
AIR FORCE RESEARCH LABORATORY
Technology
Milestones
2008

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JAN 2008	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Air Force Research Laboratory Technology Milestones 2008	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Air Force Research Lab Wright-Patterson AFB OH**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002190., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**141**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

INTRODUCTION: Click any colored section title to jump directly to that particular section in the book.

AFRL TECHNOLOGIES: Click the name of any Technology Directorate (TD) to open a new window containing the AFRL Web site for that TD.

SECTION TABLE OF CONTENTS (TOC): Click a title listed in the TOC for a given section to navigate immediately to the selected story.

FOOTER: To e-mail the point of contact for a particular milestone, click the address located in the footer for the item of interest.

Technology Milestones can be reviewed at http://www.wpafb.af.mil/news/index.asp?catid=163.
To receive more information about AFRL, visit the home page at www.wpafb.af.mil/afrl.

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AFRL Technology Milestones Program

The Air Force Research Laboratory (AFRL) is the only science and technology (S&T) organization for the Air Force. Accordingly, AFRL fulfills a mission to lead the discovery, development, and integration of affordable warfighting technologies for the nation's air, space, and cyberspace forces. Though global dynamics are continually in flux, there remains one enduring constant: sustained investment in technology is the key to ensuring our Air Force remains the best in the world.

You will find in these pages some of our most noteworthy milestones for 2008. Technologically significant in every way, these many stories yet represent only a fraction of AFRL's considerable S&T activities. As a full spectrum laboratory, AFRL plans and executes the entire Air Force science and technology (S&T) budget, providing the foundation necessary for meeting near-, mid-, and far-term military needs; preventing technological surprise; acquiring effective and affordable warfighting capabilities; and otherwise supporting a broad and balanced range of S&T-produced results.

Headquartered at Wright-Patterson Air Force Base, Ohio, AFRL achieves its S&T mission with a science and engineering workforce of approximately 5,800 government personnel, roughly 24% of whom hold doctoral degrees in science, engineering, and mathematical disciplines. In showcasing AFRL's diversity of science and engineering talent, the Technology Milestones program strives to foster information sharing and awareness throughout the technical community at large—a focus unveiling avenues of potential collaboration in areas of mutual benefit to military, industrial, and academic interests.

AFRL remains steadfast in its commitment to develop the warfighter capabilities of today and tomorrow. In thus shaping the current and future generations of air, space, and cyberspace assets, AFRL proudly fulfills its responsibility to uphold the Air Force S&T Vision.

For additional information on any of the milestones presented herein, please visit the Technology Milestones program Web site, **www.wpafb.af.mil/news/index.asp?catid=163**.

Curtis M. Bedke

CURTIS M. BEDKE
Major General, USAF
Commander

Technology Milestones Survey

Technology Milestones needs your help! As part of its ongoing commitment to bring you the highest-quality, timely, and relevant product possible, the program will soon evolve in order to better meet your needs. While your feedback is integral to this "under construction" process, we know your time is valuable...rest assured that any comments you provide are greatly appreciated and will receive careful consideration and due response. This Technology Milestones Readership survey is sponsored by the Air Force Research Laboratory (AFRL), Wright-Patterson Air Force Base, Ohio. Thank you in advance for your participation.

Purpose: This survey is intended to assess your view of Technology Milestones stories in portraying AFRL research, as well as to collect your suggestions for improvement.

1. What type of organization do you belong to?
   - ☐ USAF
   - ☐ USAF, AFRL
   - ☐ Other DoD/Military (Army, Navy, Marines, Coast Guard)
   - ☐ Other government agency
   - ☐ Industry
   - ☐ Academia
   - ☐ Other (specify): _____

2. If you are a military or civilian employee of the Department of the Air Force, what are your current primary job functions?
   - ☐ Pentagon senior decision maker
   - ☐ MAJCOM senior decision maker
   - ☐ Product Center/Logistics Center/Test Center
   - ☐ Science & Technology professional
   - ☐ Other (describe): _____

3. Do you prefer to receive a printed copy of the book, a CD, both, neither, or no preference? If you answered "neither," please tell us why.

4. What do you typically use Technology Milestones stories for? Check all that apply.
   - ☐ Overall technology awareness
   - ☐ Identification of technologies for work-related use/application
   - ☐ Identification of collaboration opportunities with AFRL
   - ☐ Identification of contract opportunities with AFRL
   - ☐ Identification of AFRL points of contact
   - ☐ Other (specify): _____

5. Which statement BEST describes your view of the value that AFRL provides based solely on the impressions formed from reading Technology Milestones stories?
   - ☐ AFRL provides technology that leads to mission/combat success
   - ☐ AFRL is responsive to operational (warfighter) technology needs
   - ☐ AFRL enhances Homeland Security
   - ☐ AFRL supports senior decision makers with viable technology options
   - ☐ Other (specify): _____

6. Please provide any other comments, questions, or recommendations you might have.

This completes your participation! Results of this survey will generate an improved product for the Technology Milestones Readership. Thank you again for your participation in this effort.

Please click the SUBMIT button to e-mail your responses to **AFRL.XPTT.DL.TechnologyMilestones@wpafb.af.mil**. SUBMIT

Introduction

The Air Force Science and Technology Milestones assembled in this book often represent the combined effort of several scientists and engineers, or groups thereof, working as a team. The basic research, applied research, and follow-on technology development efforts described herein are essential to the continued success of the Air Force mission. This book is a compilation of notable Technology Milestones selected from the following categories:

Response to Needs

Technology that demonstrates potential for, or has already achieved, application on a developmental or operational Department of Defense system and/or technology that provides "quick-reaction" response to problems or needs of field organizations

Discovery

Major innovative technological advancements that offer significant potential for existing and future Air Force systems

Demonstrations/Exercises

Examples of significant demonstration/exercise events, including flight tests, system prototype validations, joint force exercises, and similar activities

Technology Transfer

Technology that has transferred from the laboratory to the private sector, to include industry, academia, and state and local governments

AFRL Technologies

Air Force Office of Scientific Research (AFOSR)

Mission Statement: As a vital component of AFRL, AFOSR's mission is to support Air Force goals of control and maximum utilization of air, space, and cyberspace. AFOSR accomplishes its mission by investing in basic research efforts that support the Air Force mission in relevant scientific areas. Central to AFOSR's strategy is the identification of long-range technology options for national defense, as well as the timely transfer of related scientific knowledge to industry, the academic community, and government laboratories that foster developmental research leading to revolutionary technologies for the Air Force.

- Atomic and Molecular Physics
- Biomimetics, Biomaterials, and Biointerfacial Sciences
- Biophysical Mechanisms
- Boundary Layers and Hypersonics
- Ceramic and Nonmetallic Materials
- Chronobiology
- Cognition and Decision Making
- Combustion and Diagnostics
- Computational Mathematics
- Dynamics and Control
- Electroenergetic Physics
- Electromagnetics
- Electronic and Detector Material Structures and Device Concepts
- High-Density Optical Memory
- Information Forensics and Process Integration for Network Operations
- Information Fusion and Artificial Intelligence
- Laser and Optical Physics
- Mechanics of Multifunctional Materials and Microsystems
- Metallic Materials
- Optimization and Discrete Mathematics
- Optoelectronics: Components and Information Processing
- Physical Mathematics and Applied Analysis
- Polymer Chemistry
- Quantum Electronic Solids
- Remote Sensing and Imaging Physics
- Sensing, Surveillance, and Navigation
- Sensor and Detector Materials
- Sensory Systems
- Software and Systems
- Space Power and Propulsion
- Space Situational Awareness
- Structural Mechanics
- Surface and Interfacial Science
- Theoretical Chemistry
- Unsteady and Rotating Flows

Air Vehicles Directorate

Mission Statement: The Air Vehicles Directorate plans, formulates, and directs US science and technology development (research, exploratory, and advanced) for military air vehicles; orchestrates and executes technology developments in aeronautical/control sciences and aerospace structures; integrates air vehicle technologies across all AFRL technology directorates at the systems level; and orchestrates this technology development with Department of Defense and national labs, industry and academia, the National Aeronautics and Space Administration and Federal Aviation Administration, the North Atlantic Treaty Organization, and other foreign research agencies.

- Propulsion Integration
- Weapon Integration
- Experimental Aeronautical Sciences
- Flow Control/Flow Physics
- Plasma Physics
- Low-Speed Aerodynamic Configurations
- High-Speed Aerodynamic Configurations
- Multidisciplinary Computational Research
- High-Speed Computational Research
- Applied Computational Science

Control Systems and Theory
Unmanned Air Vehicle Cooperative Control
Space Access and Hypersonics Guidance and Control
Flow Control, Mechanization, and Automation
Simulation-Based Research and Development
Multifunctional Structures
Advanced Structural Concepts
Thermal Structures
Adaptive Structures
Structural Health Assessment
Computational/Analytical Certification
Combined Environments (Structures)
Multidisciplinary Design and Demonstration
Aeroelasticity Analysis Methods
Structural Integrity
Structural Dynamics
Experimental Structures

Directed Energy Directorate

Mission Statement: The Directed Energy Directorate develops, integrates, and transitions science and technology for directed energy—including high-power microwaves, lasers, adaptive optics, imaging, and effects—to assure US preeminence in air and space.

Lasers
Gas/Chemical Lasers
Electric Lasers
Bulk Solid-State Lasers
Fiber Lasers
Semiconductor Lasers, Hybrid Lasers
Laser Vulnerability and Lethality

Modeling and Simulation
Laser/Optics
Radio Frequency (RF)/Plasma
Systems
Missions

Beam Control
Atmospheric-Propagation/Adaptive Optics
Acquisition-Tracking and Pointing
Space Situational Awareness

High-Power Microwaves
Pulsed-Power Plasmas
RF Sources/Antennas
RF Effects

711th Human Performance Wing (711 HPW)

Mission Statement: The 711 HPW advances human performance in air, space, and cyberspace through research, education, and consultation. The 711 HPW merges the AFRL Human Effectiveness Directorate with the mission organizations of the 311th Human Systems Wing currently located at Brooks City-Base, Texas; the Performance Enhancement Directorate; and the US Air Force School of Aerospace Medicine.

3-D Audio
Anticipate and Influence Behavior
Aircrew Performance and Protection
Applied Biotechnology
Battlespace Acoustics and Visualization
Behavior Modeling
Biobehavioral Systems
Biomechanics
Biotechnology
Chemical-Biological Agent Defense
Cognitive Interface
Cognitive Modeling
Collaborative Interfaces
Competency-Based Performance Measurement and Tracking
Continuous Learning and Learning Management
Counterproliferation
Cultural Behavior Modeling and Representation
Cyberspace
Directed Energy Bioeffects
Distributed Mission Operations Training Research
Fatigue Countermeasures
Human-Centered Logistics Research
Human-System Interface Design
Immersive Training/Rehearsal Simulation Environments
Information Operations and Applied Mathematics

Laser Eye Protection
Live-Virtual-Constructive Integration
Logistics Readiness
Maintenance Job Aiding
Nanotechnology
Night Vision, Helmet-Mounted, and Large-Screen Displays
Nonlethal Weapons Capabilities
Operations Support
Optical Radiation Bioeffects
RF Radiation Bioeffects
Sensemaking and Organizational Effectiveness
Situational Awareness
Space
Speech-Recognition
Toxicology
Veterinary Sciences
Warfighter Readiness Research
Warfighter/Weapons Systems Integration

Information Directorate

Mission Statement: The Information Directorate leads the discovery, development, and integration of affordable warfighting information technologies for the nation's air, space, and cyberspace forces.

Information Dominance (and its transition to ground, air, and space systems, especially in the area of command and control)
Information Exploitation
Information Fusion
Communications and Networking
Signal Processing
High-Performance and Adaptive Computing
Collaborative Environments
Advanced Displays and Intelligent Interfaces
Modeling and Simulation
Information Assurance Intelligent Information Systems (including intelligent agents, planning/scheduling and decision aids, knowledge bases, and access)

Materials and Manufacturing Directorate

Mission Statement: The Materials and Manufacturing Directorate plans and executes the US Air Force program for materials and manufacturing in the areas of basic research, exploratory development, advanced development, and industrial preparedness and also provides responsive support to Air Force product centers, logistics centers, and operating commands in order to solve systems- and deployment-related problems and transfer expertise.

Accelerated Insertion Materials
Advanced Composite Processing and Behavior
Advanced Industrial Practices
Advanced Inspection
Advanced Metallics
Air Mobile Systems Research
Airbase Infrastructure
Aircraft and Spacecraft Coatings
Amorphous Metals
Analytical Chemistry Research
Atmospheric Threat Protection
Biotechnology
Ceramics and Ceramic Matrix Composites
Composites Supportability
Computational Chemistry
Corrosion Control
Electronics
Electrostatic Discharge Research
Engine Rotor Life Extension
Environmental Technologies
Firefighting Technology
Fluids, Lubricants, and Tribological Research
Force Protection Research
Hardened Materials
High-Cycle Fatigue
Hazardous Materials Elimination/Minimization
High-Resolution Flaw/Feature Imaging
High-Temperature Superconductor Materials
Infrared Sensors and Transparencies
Laser-Hardened Materials
Magnetic and High-Temperature Superconducting Materials Processing

Manufacturing and Engineering Systems
Manufacturing Processing and Fabrication
Materials Affordability Initiatives
Materials Behavior and Evaluation
Materials Life Prediction and Durability
Materials Process Design
Materials Supportability
Metallic Composites
Metal Matrix Composites
Metals Processing
Nanotechnology
Nondestructive Evaluation
Nonmetallic Composite Materials
Optical Materials
Organic Matrix Composites
Pollution Prevention Materials
Polymeric Materials
Power and Chemical Processes
Quantitative Defect Characterization
Robotics Research
Semiconductor Materials
Sensor Technologies
Solid and Liquid Lubricant Development
Structural and Electronic Failure Analysis
Superlattice and Quantum-Well Materials
Surface Phenomena/Interactions
Systems Support
Thermal Protection Materials
Virtual Reality Training
Wide-Bandgap Materials

Munitions Directorate

Mission Statement: The Munitions Directorate leads the discovery, development, integration, and transition of affordable munitions technologies for US air and space forces.

Ordnance (warheads, fuzes, and explosives)
Guidance
Computer Analysis and Modeling

Propulsion Directorate

Mission Statement: The Propulsion Directorate plans and executes the Air Force's basic research, exploratory development, and advanced development programs for flight vehicle propulsion and power technology; conducts in-house research and development to exploit new opportunities, maintain technical expertise, and verify contractor findings; provides technical and management assistance in support of studies, analyses, development planning activities, acquisition, test, evaluation, modification, and operation of air, space, and weapons systems and related equipment; provides the principal Air Force interface with scientific, industrial, educational, and other government agencies; and serves as the Air Force Materiel Command focal point in these technical areas.

Turbine Engines
Rocket Engine Test Facilities
Turbine Engine Augmentors
Solid-Fueled Ramjets
Turbine Engine Bearings
Solid Propellants
Combined-Cycle Engines
Solid Rocket Boosters
Subsonic and Supersonic Combustion
Solid Rocket Service Life
Compressors
Solid Rocket Motors
Turbine Engine Controls
Carbon Fibers and Composites
Turbine Engine Diagnostics
Ceramic Processing
Endothermic Fuels
Computational Chemistry
Engine Starting Systems
Electric Propulsion
Engine Health Monitoring Systems
High-Energy-Density Matter
Exhaust Nozzles
Injectors and Spray Measurements
Fans

Laser Propulsion
Fuel Pumps and Fuel Systems
Liquid Rockets and Combustion
Gas Generators
Micropropulsion
Gears
Monopropellants
High-Cycle Fatigue (and its mitigation)
Nontoxic Propellants
Ignition Prognostics
Plume Phenomenology
Lubrication Systems
Power Conditioning Equipment
Oil Specifications, Diagnostics, and Analysis
Propulsion Fluid Dynamics
Oil Monitors
Rocket Materials
Optical Diagnostics
Rocket-Based Combined-Cycle Engines
Pressure-Sensitive Paints
Solar Propulsion
Pulsed-Detonation Engines
Thermal Management
Scramjets (supersonic combustion ramjets)
Thermionics
Seals
Auxiliary Power Units
Turboramjets
Batteries and Fuel Cells
Turboshaft Engines
Capacitors
Very Short Takeoff and Landing Propulsion
Circuit Breakers
Air Turborockets
Converters/Inverters
Hybrid Rockets
Electric Motors
Intercontinental Ballistic Missile Propulsion
Conventional and Superconducting
Liquid-Fueled Ramjets
Generators

Sensors Directorate

Mission Statement: The Sensors Directorate leads the discovery, development, and integration of affordable sensor and countermeasure technologies for the warfighter.

RF Sensing
Electro-Optical (EO) Sensing
RF Electronic Warfare
EO Electronic Warfare
Automatic Target Recognition/Performance Driven
Sensing Enabling Sensor Devices Components Trusted
Collaborative Sensing

Space Vehicles Directorate

Mission Statement: The Space Vehicles Directorate develops and transitions innovative high-payoff space technologies supporting the warfighter, while leveraging commercial, civil, and other government space capabilities to ensure America's advantage.

Aerospace Environment Warfighting Systems
Revolutionary Space Capabilities for Global Awareness
Vital Developing Military Space Concepts

Response to Needs

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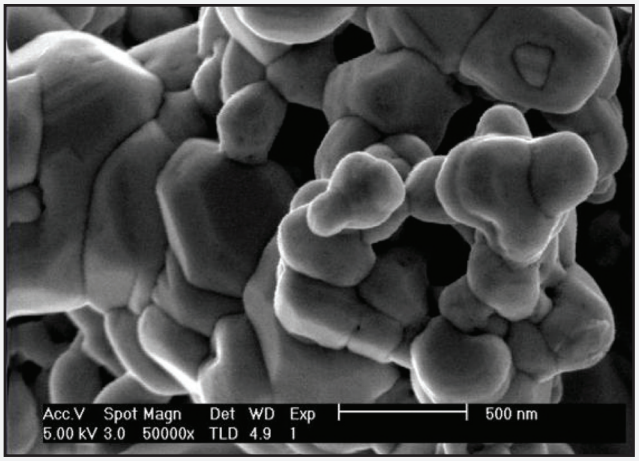
Researchers Create Family of Composite Materials

AFRL-funded researchers have constructed an entirely new class of materials that could potentially aid Air Force (AF) missions. Dr. David Avnir, head of the Institute of Chemistry at The Hebrew University, Jerusalem, Israel, led the scientists whose initial research yielded this surprising outcome. The idea of combining organic molecules with metals opens the door to many possibilities, and the range of preparation methods heightens the chance of finding useful end applications for AF missions. According to Major Jennifer Gresham, the program manager who oversees Dr. Avnir's work, the technology's two most promising applications involve corrosion resistance and improved catalysis for fuel cells.

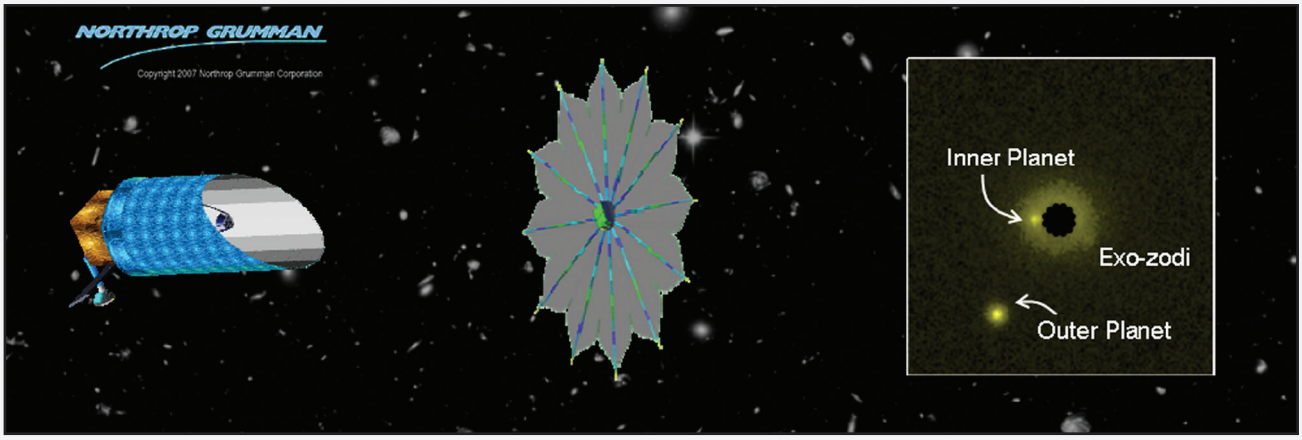
Preliminary indications suggest that the new metallic composites exhibit improved corrosion resistance. This finding is significant because metal corrosion is a persistent problem for the military and industry alike, impacting 3% to 5% of the gross national product of industrialized nations. In the US, this percentage translates to $280 billion each year. The technology's demonstrated usefulness includes its capacity to accelerate industrial processes through the physical alteration of metal properties and the formation of new metallic catalysts offering superior performance.



Microscopy picture of an organic polymer and silver composite

Silver and copper composites are especially advantageous; the known antibacterial properties of these metals are of particular benefit in applications requiring long-term sterility, such as in plane and space station compartments and emergency medical treatment facilities and equipment. Dr. Avnir and his team devised methods wherein the metal is prepared at temperatures compatible with the organic molecules being trapped. With AFRL's funding support, the team was able to develop four different laboratory methods, subsequently applying these techniques to copper, silver, cobalt, gold, and palladium.

Mathematician Aids Effort to Observe New Worlds



The "New Worlds Observer" project involves a 50 m starshade positioned between a generic space telescope and a star. It blocks light so that any planets in proximity to the star become visible (image courtesy of Northrop Grumman).

The applied methodologies of AFRL-funded mathematician Dr. Oscar Bruno are an instrumental part of a project aimed—quite literally—at discovering new planets. Dr. Bruno researches numerical methods and develops the resulting software that, in turn, predicts the interaction of electromagnetic waves, such as radar and light, with structures of interest to the Air Force. AFRL has a history of supporting Dr. Bruno's scientific endeavors, having sponsored both his research as a small business owner through the Department of Defense Small Business Innovation Research/Small Business Technology Transfer program and his efforts as a research scientist at the California Institute of Technology.

Dr. Bruno is currently investigating the dynamic interaction of radar waves and aircraft surfaces; as the waves hit an aircraft's surface, they cause it to behave like a radiating antenna. This phenomenon may be a desirable effect in some—but by no means all—situations. Dr. Bruno's software predicts radiation patterns based on the shape and composition of an aircraft, which enables researchers to rule out variations that produce unwanted results. There is significant value to software capable of producing such predictions; without it, researchers would have to resort to slow, expensive, trial-and-error efforts in order to create and evaluate a range of geometric shapes.

Northrop Grumman Space Technology (NGST) contracted with Dr. Bruno for the company-funded "New Worlds Observer" project. NGST researchers perform investigations by placing a flat, 50 m structure called a starshade between a space telescope and a star. The structure blocks all visible light emitting from the star, allowing the observer to instead view the extremely dim light coming from any planets located in the star's vicinity.

Dr. Bruno and graduate student David Hoch developed a code that provides 16-digit accuracy, works within a 70 sec window, and runs on an ordinary desktop computer. The two continue to work on the corresponding simulation tool and expect to deliver a complete code package early in 2009.

Dr. Bruno's contributions will permit scientists to map and catalogue planetary systems proximal to observed stars, ranging from "warm" planets (i.e., those with close-in orbits around their parent stars, similar to Earth and Venus) to frozen giants located at the edges of distant solar systems.

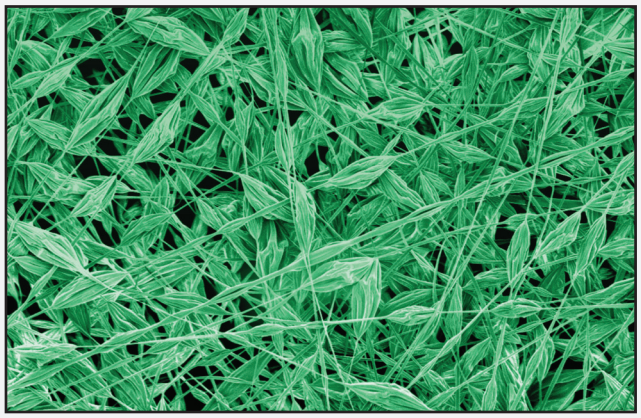
For more information contact
publicaffairs@afosr.af.mil • (703)696-7797

AFRL Funds Research of Oil-Repellent Surfaces

AFRL is sponsoring investigations of super-oil-repellent surfaces for their potential utility in cleaning up jet fuel spills and protecting aircraft or rocket parts from fuel absorption. Dr. Gareth H. McKinley and Dr. Robert E. Cohen, professors of engineering at the Massachusetts Institute of Technology (MIT), are exploring man-made and natural surfaces that prevent gasoline and oil from soaking in and spreading out. The challenge lies in the low value of surface tension characteristic to many oils. Surface tension is a measure of the attraction existing between molecules of the same composition; the low value of surface tension (i.e., weak molecular attraction) inherent to most oils permits them to spread very easily over surfaces. Consequently, the researchers' goal is to design new solid surfaces exhibiting very low interfacial energies and thus capable of repelling oily liquids.

After studying the water-repellent surfaces of lotus leaves, Drs. McKinley and Cohen created a microfiber-based fabric that can be deposited onto aircraft surfaces via a process known as electrospinning. The microfibers contain Fluoro POSS, or fluorinated polyhedral oligomeric silsesquioxanes—a unique type of fluorinated nanoparticle synthesized by Dr. Joe Mabry and colleagues at Edwards Air Force Base, California.

The combination of the involved chemistry on the nanoscale level and corresponding fiber structure on the micrometer scale gives rise to the new material's substantial oil-repelling nature. Research targeting the exploration of oil-repellent surfaces is critical for the preservation and advancement of many Air Force systems. This collaborative effort between scientists at MIT and AFRL marks an important step towards achieving future systems that are inherently more maintenance-free.



This graphic shows the magnification of FluoroPOSS, which repels both water and oil.

The scientists' work may ultimately lead to viable protective coatings for airplane parts that are vulnerable to fuel leaks. Their research may also prompt the creation of fuel-line gaskets based on the new technology, since currently available gaskets are known to swell substantially when they absorb gasoline. Such material-related innovations will greatly reduce the maintenance effects of fuel spills as well, making cleanup of fuel or oil-soaked equipment significantly easier.

AFRL Conducts New Air Force Aircrew Anthropometry Study

Mr. Scott Fleming (pictured left), anthropologist with AFRL's 711th Human Performance Wing's Human Effectiveness Directorate, positions AFRL Vice Commander Col David B. Glade II in the lab's three-dimensional whole-body surface scanner as he explains how the body measurement process works (photo by AFRL's Chris Gulliford).

The last time the Air Force (AF) conducted a large-scale anthropometric (human body measurement) survey of its pilots was 1967. Countless changes have occurred since then, one of which being the average size and shape of the human body. The critical significance of this evolution is evident in AFRL's present effort to update outdated anthropometric data by measuring 3,000 representative members of today's AF aircrew.

In 1967, researchers used traditional tools, such as tape measures and calipers, to take body measurements. While today's researchers continue to rely on these conventional instruments, they also have at their disposal an advanced capability: three-dimensional whole-body surface scanning. This technology, which permits the humanlike animation apparent in movies such as *The Polar Express*, enables the extraction of innumerable measurements in just a few seconds.

To emphasize the importance of the project, AFRL Vice Commander Colonel David B. Glade II—himself a command pilot and experimental test pilot with 2,700 hrs in more than 60 different aircraft types—volunteered as one of the first test subjects. The results of this historic research will feed into the newly established Integrated Aircrew Ensemble program, an effort under way at Brooks City-Base, Texas, and slated to produce the next-generation head-to-toe life support system for AF aircrew in about 5 years.

The anthropometric information generated by AFRL's study will help engineers improve sizing and similar design characteristics of AF aircrew clothing; workstations and other equipment; and personal protective gear such as body armor, wherein proper fit equates to personnel safety. Further, the same design improvements geared towards enhancing aircrew comfort and protection will ultimately reduce the costs associated with improperly fitting products as well.

The designers responsible for the AF's existing flight gear based their recommendations on a 1988 US Army survey. They did so because (as stated) the last extensive effort to collect AF aircrew data had occurred in 1967—long before women and many ethnic minorities had become an integral part of the full-time AF pilot population, and at a time when military pilots were primarily young, Caucasian males who were relatively physically fit. Current Air Force Personnel Center statistics reveal a vastly different demographic makeup. Today's AF has 13,065 active-duty pilots—a figure that encompasses 559 females and a variety of ethnicities. This diversity translates to an expansive range of human factors—including age and body type, shape, and size—that must be considered and adequately addressed. Consequently, AFRL's updated anthropometric data will assist the AF in better outfitting and protecting its servicemen and women of today.

For more information contact
afrl.rh.tech.info@wpafb.af.mil • (937)255-3814

F-35 Speech Recognition System Undergoes Fine-Tuning

Due in part to testing and analysis conducted at AFRL, the F-35 Lightning II will be the first US fighter aircraft equipped with a speech recognition system capable of "hearing" a pilot's spoken commands to manage various aircraft subsystems, such as communications and navigation. AFRL researchers are in the process of collecting data and recommending various improvements geared towards ensuring optimal performance of the F-35's new speech recognition system as it undergoes future operational tests.

Currently, pilots must press buttons, flip switches, or glance at instruments to obtain status information. The new system, SRI International's DynaSpeak® product, not only simplifies pilot workload but increases safety and efficiency, since it allows pilots to remain focused on flying the aircraft and scrutinizing the combat environment. To fine-tune the new capability, researchers are using digital recordings from in-flight tests aboard the NF-16D variable-stability in-flight simulator test aircraft (VISTA) to pinpoint problem phrases—those that could be difficult to interpret or are otherwise ambiguous—and recommend alternatives that are more easily recognized. They are also tweaking error parameters and adjusting the system's sensitivity for peak speech recognition performance with minimal errors.

SRI International developed DynaSpeak as a highly accurate system for use in noisy environments—specifically, for embedded devices such as personal digital assistants, in-car navigation systems, and avionics systems. It is speaker-independent, meaning that a pilot can use the system without first "training" it to perceive his or her voice, a process taking up to an hour with previous experimental systems. SRI International is working with integrating contractor Adacel Systems, Inc., to tailor the system for the F-35 Joint Strike Fighter's airborne environment.

F-35 Lightning II Joint Strike Fighter (Navy photo by Chief Petty Officer Eric A. Clement)

Leveraging resources at the US Air Force Test Pilot School (Edwards Air Force Base, California), the AFRL team worked with six pilots whose primary mission for the effort was flying VISTA test bed sorties to collect speech recognition data. The resultant digital recordings enabled the team to study troublesome phrases, as well as the impact of environmental factors on acoustic characteristics. While ambient cockpit noise degrades the quality of spoken commands entering the recognition system, which could cause errors of misinterpretation or misunderstanding, acceleration forces up to approximately 6 *g* have little effect on the system's performance. If proven successful on the F-35, this baseline speech recognition system could be advanced for incorporation into aircraft such as the F-22 Raptor and future unmanned air vehicle platforms.

US/UK Collaboration Produces New Military Laser Safety Code

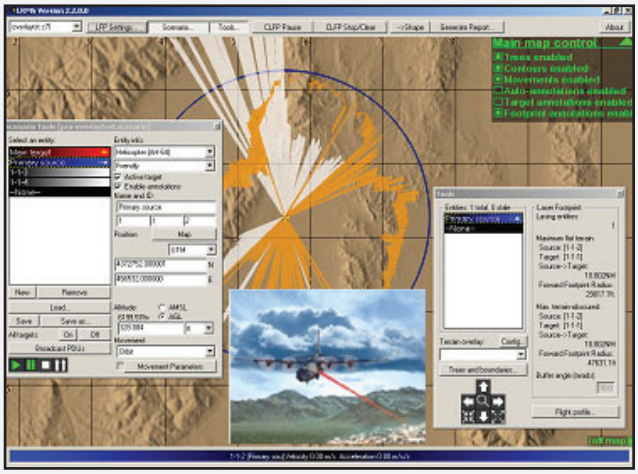


Illustration of new US/UK laser range safety tool facilitating probabilistic risk assessment

AFRL's High-Energy Laser (HEL) team successfully completed a 3-year effort to develop a new international agreement expanding an existing collaboration between the US and the United Kingdom (UK). The new project arrangement, entitled "Probabilistic Risk Assessment (PRA) Methods for Military Laser Safety Predictions," authorizes a 5-year (2007-2012), $1 million effort to develop, test, and evaluate a PRA-based laser range safety tool. This new, jointly owned tool will replace the deterministic safety models currently used in the US. Likewise, it will become the universal tool for performing laser safety analyses in support of low- to moderate-power military laser use on US and UK ranges. The use of a common PRA technique, incorporated into a common tool, will enable laser safety officers to perform identical calculations, facilitating joint exercises on Department of Defense (DoD)/Ministry of Defence (MoD) ranges.

Researchers from AFRL and the UK's Military Laser Safety Committee began collaborating in November 2001 to develop military laser safety models based on PRA techniques. The motivation for this joint effort stems from a widespread belief that the deterministic models currently employed for US military laser safety analysis will be inadequate for addressing future DoD safety needs—especially those related to HEL testing, training, and deployment. Conversely, the MoD has been using PRA-based hazard analysis to support military laser tests at UK ranges for the past 20 years.

Modeled after the PRA tool used for the UK's TIALD [Thermal Image and Laser Designator] system, the jointly owned capability is known as the Military Advanced Technology Integrated Laser Hazard Assessment (MATILDA). AFRL scientists have completed and shipped MATILDA code Versions 1.0 and 1.2 to their UK counterparts for test and review. Spiral development of MATILDA code will occur over the next 4 years, with each new version building on the previous release and containing new features and functionality.

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Next-Generation Threat System Transitions to Navy

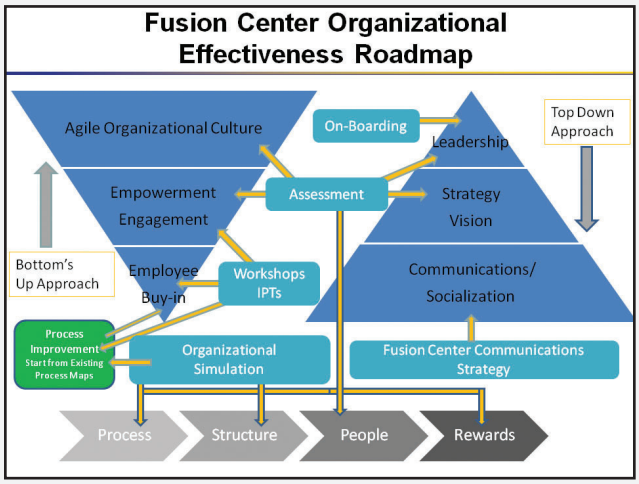
AFRL transitioned the Next-Generation Threat System (NGTS) to the Navy and continues to provide system updates stemming from ongoing research and development (R&D). The Advanced Technology Demonstration (ATD) from which the system transitioned addresses a number of critical problems with legacy electronic combat environments (ECE), including high procurement and sustainment costs and difficulties both with verifying, validating, and accrediting proprietary systems and with procuring a different system for every new training device that surfaces. In a published statement concerning the F-18 simulator top-ten lists, the US Navy indicated that implementing the Naval Aviation Simulation Master Plan (NASMP) would require development of a capable and realistic threat environment. Consequently, the Navy has played an active role in fulfilling the intent of AFRL's goals towards developing and transitioning the NGTS technology.

AFRL's Warfighter Readiness Research Division is constantly redefining team training methods and, as such, engages in several ongoing efforts involving the ECE, or electronic attack/electronic warfare (EA/EW), aspects of training. Over time, the models produced from this focus have evolved—thanks to the influence of continuing R&D—into a physics-based approach to ECE. Accordingly, what originated as a proof-of-concept ECE—The Next Threat System—grew into the ATD known as the NGTS. AFRL transitioned this new technology both to the distributed missions operations community (including the Division Tactical Operations Center, in support of large-force virtual flag exercises) and to Naval Air Systems Command (to support NASMP implementation). The system's real-time, easily updated, data-driven format has not only met the approval of the warfighter community, but has bolstered related science and technology (S&T) activity in other regimes and generated interest from other Department of Defense organizations.

Logo for XCITE

Because AFRL ultimately expanded its EA/EW threat modeling and simulation S&T to encompass theater and live-virtual-constructive environments, the NGTS has undergone an associated name change. The newly designated "eXperimental Common Immersive Theater Environment," or XCITE, is a powerful developmental tool. Used throughout AFRL's many and varied S&T programs—and also to power several test beds—XCITE provides a rapid prototyping environment wherever a real-time, high-fidelity, computer-generated-forces system is needed.

Fusion Center Organizational Effectiveness Targets C2 Domain



FCOE program roadmap

Researchers briefing US Transportation Command (USTRANSCOM) and Tanker Airlift Control Center leadership on the lab's progress towards Fusion Center Organizational Effectiveness (FCOE) received positive feedback on the effort's first-year activities. Paramount to the program's high regard was its ongoing emphasis on collecting data needed both for better understanding sustainment and Deployment and Distribution Operation Center processes and for more accurately populating command and control (C2) simulation models. FCOE researchers will continue working to identify and investigate areas for improvement, leveraging regular interaction with commercial off-the-shelf software developers regarding potential code changes that could support emerging research paths.

The FCOE program applies organizational psychology principles to the investigation and understanding of organizational change as it occurs in the C2 domain. The product of a Memorandum of Agreement between AFRL, Air Mobility Command, and USTRANSCOM, the 3-year program merges multiple methodologies, theories, and tools to examine modeling and simulation, organizational assessment, workspace design, and change management aspects of organizational change. This multimodal approach accommodates data triangulation, maximizing the breadth of findings while providing integrated warfighter support. FCOE is addressing the dynamics of major organizational change within USTRANSCOM. This program will contribute not only to future C2 environment research, but to current organizational psychology literature with regard to large-scale organizational change efforts in the government.

In the context of the C2 environment, FCOE explores organizational change with respect to its impact on the warfighter. Accordingly, FCOE efforts encompass a range of organizational effectiveness and change theories and information processing models. FCOE researchers employ these diverse theories and models to gauge personnel readiness for change, explore collaborative readiness metrics, and optimize organizational designs. By aligning various elements of organizational effectiveness with recommended change interventions commensurate with a given organization's change readiness and capabilities, these results aid leadership in realizing strategic change management.

The FCOE program also facilitates the C2 environment's use as a test bed for developing research avenues for POW-ER, an organizational modeling and simulation tool based on years of research conducted by the Stanford University's Virtual Design Team (VDT). AFRL and Stanford VDT are collaborating on ways to extend POW-ER's use to semistructured, information-driven C2 tasks. POW-ER has thus far enabled AFRL to model a "fused" organizational structure and simulate possible organizational changes—such as combining tasks or designing a new collaborative work group—in order to determine high-impact organizational changes.

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Standard Space Trainer Offers Expanded Simulation Features

SBIR–developed standard space trainer

The Air Force needs an integrated simulation-based training and rehearsal capability for schooling operators in satellite system ground control. Working under a Small Business Innovation Research (SBIR) grant, engineers from AFRL and Sonalysts, Inc., developed a standard space trainer (SST) for use as a proof-of-concept instructional simulation tool. In addition to supporting multiple systems, the SST offers advantages such as flexible control features for instructors, increased productivity for instructors and students alike, quick setup, and lower training costs. As a result of this prototype's success, the SST hardware and software architecture, two satellite training software applications, and the associated sustainment of these products are now planned as Air Force Phase III acquisition deliverables.

The SBIR-produced technology incorporates advanced modeling, simulation, and visualization elements, providing sophisticated instructional simulation support for a subset of Architectural Evolution Plan and Defense Satellite Communications System satellite systems. Engineers designed the prototype SST mindful of a twofold goal: to evaluate the potential use of a personal-computer-based microsimulation environment for conducting initial skills training and unit-qualification training in the area of satellite command and control, as well as to provide a stepping stone towards the development of a production-level SST system.

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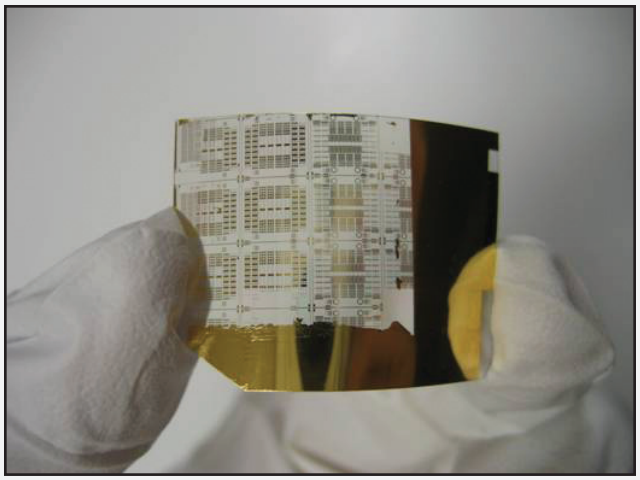
Scientists Demonstrate Record Performance Speeds for Bendable Electronics



The flexibility of superthin silicon transistors (pictured) could lead to electronics attached to unevenly shaped objects such as airplane bodies or engines (image courtesy of Dr. Jack Ma).

AFRL sponsored the development of electronics that are not only fast in terms of processing speed but also bendable, a characteristic that enables their attachment to unevenly shaped objects such as airplane bodies or engines. The research team behind the success of this endeavor, led by University of Wisconsin-Madison scientist Dr. Zhenqiang (Jack) Ma, first developed superflexible silicon chips capable of withstanding impact and severe vibration. The team's subsequent addition of pressure to these durable chips generated performance speeds up to 50 times faster than the processing speeds achieved previously via similar efforts.

The scientists are now working on a variation of this bendable electronics technology in the form of flexible photodetectors, or optoelectronics. Optoelectronic devices are important to applications wherein high-speed photography is a priority, and a newfound capability to arrange these devices in a hemispherical or spherical shape will enable surveillance of respective regions of interest with no need for a moving lens.

Further, this research has produced a number of innovative methods for manipulating the flexible nanomembranes associated with the technology as well. These novel methods will permit relevant electrical properties to be tailored at will. These lab-sponsored research results are both timely and relevant for the Air Force (AF) and Department of Defense, as well as for the semiconductor material and device component industries. The AF can leverage the outcomes for its numerous new flexible electronics and optoelectronics applications, which include compact antennae that attach to airplane bodies and missiles, flexible sensors that detect mechanical changes, and 360° air surveillance. Overall, the capacity to synthesize and manipulate extremely thin films of solid-state materials facilitates wholly new approaches for improving the performance of defense and commercial systems while reducing the corresponding size, weight, and power requirements of these systems.

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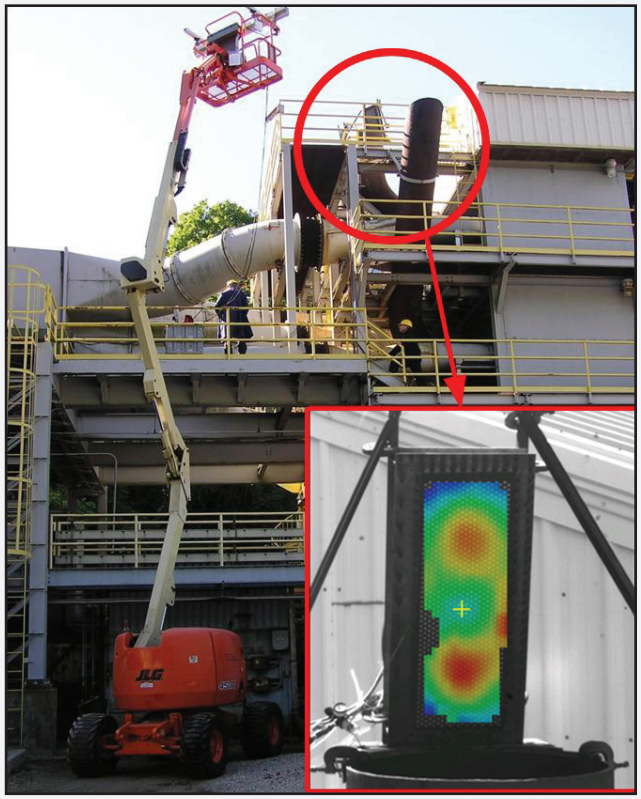
Deformation Measurements Validate B-2 Aft Deck Performance Models

AFRL engineers devised a way to measure deformation in modeled materials simulating those used for the B-2 bomber aft deck. Located behind exhaust nozzles on the aircraft's upper surface, the aft deck experiences repeated thermal and vibro-acoustic stresses at levels sufficient to cause premature fatigue cracking. Measuring deformation is an effective means of validating the reliability of material models used in determining aft deck mechanical response. The engineers used live ground-engine test cell runs and a test specimen to demonstrate the proposed deformation measurement system's performance. These tests reinforced previous findings. The results also confirmed the reliability of a three-dimensional (3-D) image correlation technology developed by GOM Optical Measuring Techniques, an international company headquartered in Germany.

Measuring the degree of deformation occurring as a result of thermal and vibro-acoustic stresses is a viable way to identify the deck's fatigue cracking potential. Therefore, the primary objective of the engine test runs executed for this effort was to assess the reliability of an emerging, nonintrusive deformation measurement technology in order to ensure its equitable performance when utilized in the field.

AFRL selected a powerful measurement technology known as ARAMIS 3-D image correlation. ARAMIS inspects complex materials and geometries for deformation and strain during loading. It offers a noncontact, material-independent capability to determine deformation and strain using 3-D video correlation methods and high-resolution digital cameras. One or more high-resolution digital cameras view the object under load. The resulting image reveals a clearly visible random or regular structure that has been correlated to the object's surface and thus undergone deformation along with the object. The cameras record the deformation under different load conditions, and the results—3-D displacement, tangential strain, and component contour—undergo evaluation via digital image processing.

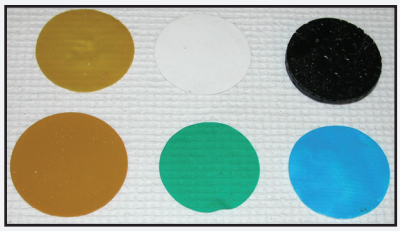


Engine test run configuration, including manlift with mounted camera bar and test specimen (circled). Photo inset (outlined) depicts 3-D map of test specimen showing out-of-plane deformation due to thermal expansion.

AFRL engineers worked with the 780th Test Squadron Aerospace Survivability and Safety Flight team to design and set up the engine test runs necessary for examining ARAMIS system performance. The AFRL team configured the thermal imaging cameras and mounting structures; provided technical support to Trilion Quality Systems, the US-based ARAMIS vendor; handled heavy equipment requirements; and supplied and installed instrumentation needed for conducting the test runs.

Barrier Coating Exploration Key to Protecting Military Facilities and Personnel

AFRL research scientist Mr. Scott MacLean applies a barrier coating to a large-scale test facility at Tyndall Air Force Base, Florida.



Barrier coating sample coupons

Researchers from AFRL, the Defense Threat Reduction Agency (DTRA), and the Joint Science and Technology Office (JSTO) joined forces to conduct extensive research on materials technologies with the potential to protect military structures against chemical warfare agents. The research, which is ongoing, has already helped DTRA define parameters concerning structural protection of this nature. It will also assist the agency's efforts to identify products capable of protecting military personnel from harmful chemical warfare agents that may be used against them, both at home and in forward operating locations. The successful results have prompted the decision to transition select barrier coating products to the Joint Expeditionary Collective Protection (JECP) program. Inexpensive and easy to apply, the transitioning technology will save both money and time.

Facilities such as the tents, medical buildings, and offices where military personnel perform their duties need to be protected from the threat of permeating chemical warfare agents should such an attack occur outside the structure. Consequently, DTRA and JSTO initiated a research program with AFRL and in-house contractor Applied Research Associates, Inc., to begin identifying and testing commercial off-the-shelf products that may meet this critical need.

The researchers sought products that field personnel could apply quickly and easily to the inside of a structure. They wanted a product that would not only stop air inside the structure from leaking out, but also protect the structure's vulnerable areas from penetration by a chemical released outside. It was also essential that the product's application demand only simple tools, such as paint sprayers. Based on these criteria, the team selected for in-lab and large-scale tests six commercial products: ALARA 1146, Tubcoat 4410, Stripcoat TLC Free, LINE-X, Olympic latex paint, and sandable polyurethane foam.

Though their research continues, team members have already identified two of the chosen products—ALARA and Tubcoat—as practical protective solutions for mitigating chemical threats. These nontoxic, water-based coatings are readily applied to a facility's interior, where they quickly dry to provide a suitable protective barrier that can later be peeled off the structure. JSTO officials are so pleased with this research outcome that they have launched plans for transitioning the technology to JECP this year.

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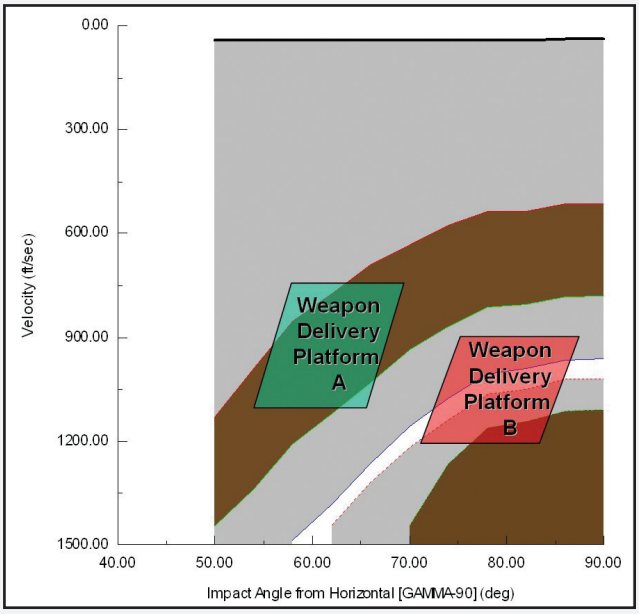
Response Surface Mapping Technique Aids Warfighters

AFRL scientists, collaborating with other Department of Defense agencies, applied innovative response surface mapping (RSM) data mining and visualization methods to aid the efficiency and effectiveness of warfighter weaponeering decisions. A team of scientists from AFRL and the US Army Engineer Research and Development Center integrated the RSM algorithms into the three-dimensional (3D) projectile penetration code (PENCURV+), creating PENCRV3D_RSM. The PENCRV3D_RSM software automatically performs hundreds of weapon penetration trajectory simulations before integrating the results into a single RSM chart so that planners can visualize the comprehensive data. An invaluable tool for analysis activities requiring the execution of numerous parametric simulations, PENCRV3D_RSM augments efforts such as mission planning, weapon development, and unexploded ordnance work.

When weaponeering a target, military planners pinpoint a detonation location that will result in the desired damage to the entire target, or even a particular area within the target. The warfighter then selects the most suitable delivery platform—aircraft, weapon, guidance package, release altitude, and speed—for inflicting maximum damage to the target. Determining the proper combination of variables capable of producing the desired effect on a hardened target requires the warfighter to understand the penetration dynamics of the weapon. Doing so also relies on the individual's ability to adjust the variables within his or her control, as necessary. For a scenario in which the destruction of a specific target is often coupled with the mitigation of collateral damage, it is imperative that the warfighter make proper decisions regarding weapons selection.



Velocity graph of weapon delivery platforms

Prior to the implementation of the RSM techniques, mission planners made an initial assumption of release conditions. If the weapon failed to achieve the desired penetration depth, the planner selected either a new set of release conditions or a different weapon and then ran the analysis again. The advent of the RSM approach enables mission planners to run a single analysis to determine the penetration outcome for multiple guidance kits and release conditions.

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AFRL/Industry Team Conducts Successful Radar Seeker Test

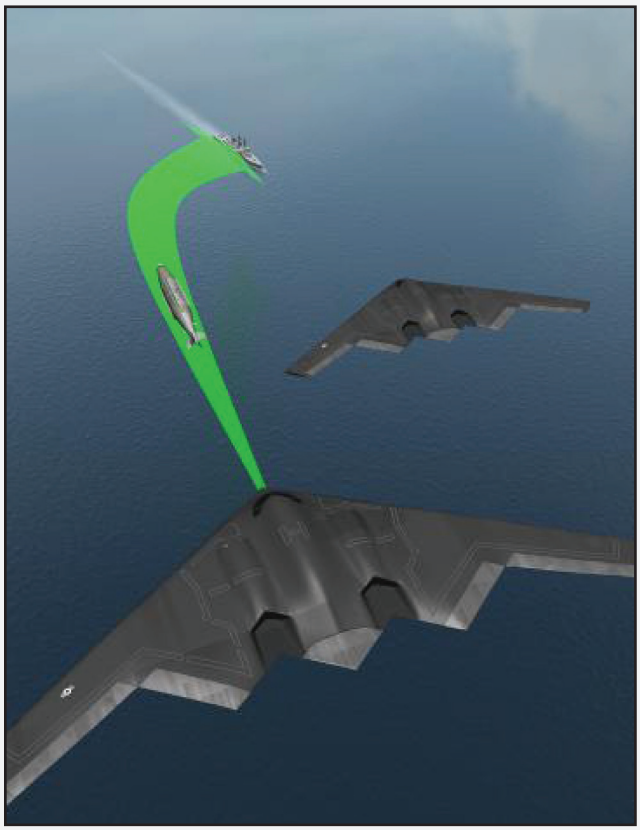

Illustration of FALCON EYE seeker's engagement of a surface vessel

Researchers from AFRL and radar technology company Mustang Technology Group completed a series of captive flight test activities for the FALCON EYE seeker program. The FALCON EYE program focuses on the integration of low-cost technologies that collectively provide autonomous engagement capabilities against potential maritime mobile threats. As part of the ongoing evolution of Air Force (AF) guided weaponry, the FALCON EYE seeker increases the warfighter's capacity to engage moving and stationary surface targets regardless of environment and/or weather conditions.

For the recent test activity, the research team employed a newly developed software-controlled radar seeker consisting of a wide-field-of-view monopulse antenna and radio frequency (RF) front end, an assembly constructed entirely from inexpensive commercial off-the-shelf components. The seeker was integrated into a lightweight twin-engine aircraft and controlled by a non-form-factored digital processing unit. The researchers collected data pertaining to seeker performance against a variety of surface targets. In addition to validating the seeker's range and directional performance, the data is also assisting the refinement of related algorithms and simulations. The AFRL/industry team will continue this progressive development effort by form-factoring the seeker's digital back end, coding its algorithms, and completing its integration with the RF front end.

FALCON EYE is laying the groundwork necessary for providing the AF a simple, affordable approach to attacking a broad range of mobile target threats. Easily integrated into a wide variety of weapon systems, the small, modular configuration successfully leverages a variety of low-cost, high-performance components emerging in the electronics market.

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Flight Tests Validate Concept Vehicle for Bomb Damage Assessment

AFRL researchers conducted successful flight test of Voyeur, a proof-of-concept rotary wing unmanned air vehicle (UAV) designed for bomb damage assessment (BDA) missions. Lite Machines Corporation developed the coaxial counterrotating helicopter under a Small Business Innovation Research contract. The UAV's compact size and nominal weight, coupled with its unprecedented flight capabilities, represent unparalleled qualifications for the selected mission.

Flight test of Voyeur, a proof-of-concept rotary wing UAV

BDA entails the reconnaissance activity that occurs following a munition's impact; these missions confirm the weapon's target destruction effectiveness. BDA poses difficulty because strike zones are typically controlled by hostile forces and thus not accessible for close examination. High-altitude photographs taken by satellites and orbiting aircraft often lack timeliness and surface detail resolution. Meanwhile, low-altitude, close-range examination via manned aircraft is often prohibitive due to insufficient room for maneuvering and high probability of hostile fire. The dirty, dangerous nature of these obstacles underscores UAVs as a well-suited option for performing BDA, given their capability to supply the clear, concise, close-in sensor data that is ideal for assessment tasks.

Voyeur employs two counterrotating coaxial rotors, which provide increased lift and maneuverability while eliminating the need for a tail rotor. An active stability system makes the aircraft both more stable and more maneuverable than traditional rotary wing UAVs, which rely on passive stability supplied by linked rotors. The vehicle's capacity for hovering stability facilitates the operation of onboard sensors from a stationary position, enabling BDA even in cluttered urban environments and providing unquestionable confirmation of target destruction moments after the impact event.

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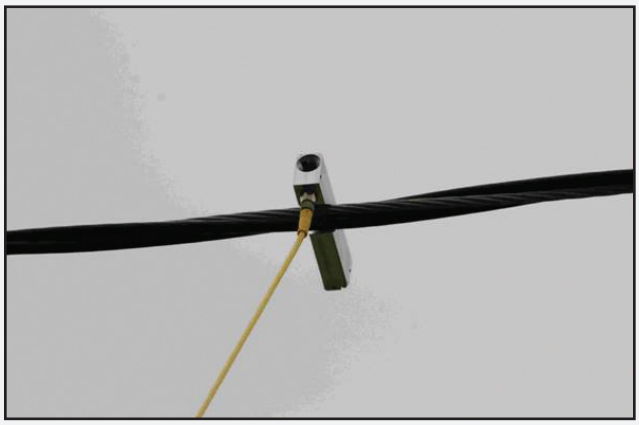
Remote Auxiliary Power System Solves Power Harvesting Problems



RAPS metal sensor head, nicknamed the "bat hook," hangs over a power line.

At the request of Air Force Special Operations Command's Special Tactics Squadron, AFRL engineers addressed an urgent operational need to solve the problem of recharging batteries in forward locations. The resulting remote auxiliary power system (RAPS) allows military forces to harvest power from any low-voltage (<600 V) transmission line in order to recharge chemical batteries in the field.

Power harvesting is based on the premise that there are plenty of power lines available even in third-world countries. The availability of a system designed to tap into these power sources for military use translates into opportunities for nearly unlimited operational endurance. Lacking such a capability, Special Forces personnel have had no choice but to carry a fresh supply of new batteries, burdening them with added weight and further diminishing their rucksack's already limited storage capacity. As an alternative, solar cells work fine when there is sunlight, but they have poor overall efficiency.

RAPS engineers were concerned about the dangers of making ground-level connections to high-voltage power lines but initially ignored the possibility of using lower-voltage lines, which use insulation that prevents a good electrical connection from ground level. Instead, engineers first concentrated on devising a safe method of transferring power from high-voltage power lines. However, after approximately 5 months of research, the engineering team decided to reexamine the feasibility of using low-voltage power lines. The RAPS method and its associated apparatus emerged as a direct result of this inspiration, solving not only the power-limitation problems of forces on foot in the field, but the significant safety issues as well.

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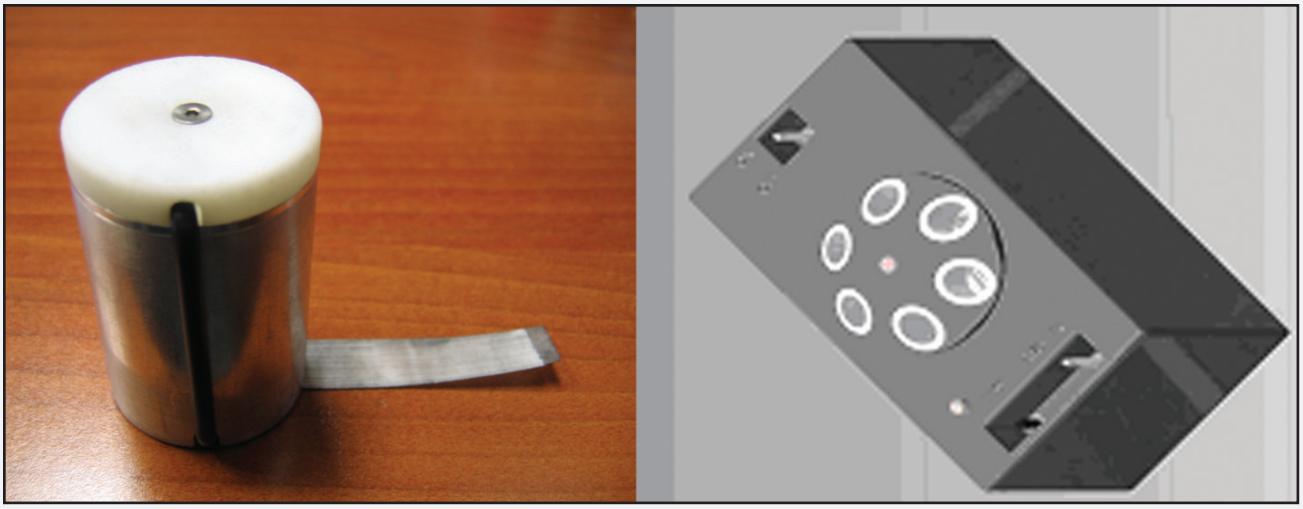
Rapid Response Effort Generates Friendly Marking Devices

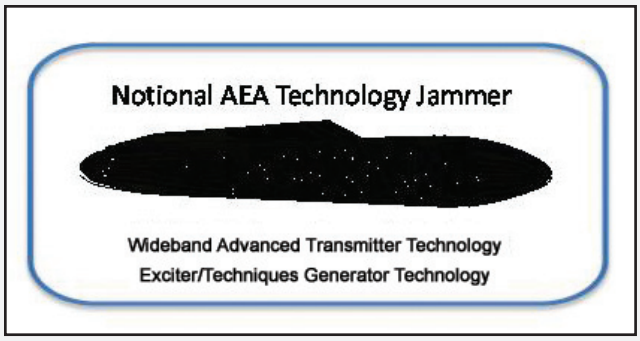


SM FMD and advanced FMD

Prompted by AFRL's initiation of a rapid reaction project, a team of systems engineering graduate students from the Air Force Institute of Technology succeeded in developing advanced friendly marking devices (FMD) that can be detected by an aircraft targeting pod. The AFRL Core Process 3–driven effort called for development and field test of an FMD detectable by means of targeting pod camera or laser spot tracker. The student team received technical assistance from AFRL sensors scientists in completing the effort, the results of which will enable forward air controllers/joint terminal attack controllers to provide accurate nonvisible reference marks that enable close air support assets to attack intended targets while avoiding fratricide.

AFRL scientists assisted the student team in performing the systems engineering tests necessary for formulating several potential solutions. During subsequent demonstration and test of these solutions at Nellis Air Force Base, Nevada, the two AFRL-developed prototypes proved the most viable of the possible solutions. In response to these promising results, AFRL sensors scientists completed in-house development of an electrical FMD and also worked closely with Alloy Surfaces Company to create a special-material (SM) FMD visible from greater distances. While the SM FMD is now available commercially and will soon undergo field trial by Air Force users as well, the advanced FMD requires additional work to refine its design.

Airborne Electronic Attack Technology Maturation Program Awards Milestone Contracts



AFRL AEA Technology Maturation program logo

AFRL's Airborne Electronic Attack (AEA) Technology Maturation program achieved a major milestone with the award and kickoff of multiple, 3-year technology demonstration contracts. The awarded contracts have a combined value of more than $56 million. The awardees—Boeing, ITT, Northrop Grumman Electronic Systems, and Raytheon—face significant and challenging technical risks in maturing the critical technologies and major subsystems for anticipated transition to the (planned) B-52 Core Component Jammer program. Ultimately, the matured capabilities will likely transition to the Navy's EF-18G Next-Generation Jammer effort as well.

Among the critical technology objectives addressed by these contracts are the development of high-power wideband-array transmitters and exciters/techniques generators, as well as the systems engineering and integration of these arrays and exciters/techniques into a stressing aircraft pod environment. This program has successfully forged strong ties with the acquisition communities, Navy peer technology developers, and the Air Force warfighter requirements organization. The end-state objective of this effort is to successfully mature, demonstrate, and transition multiple technologies and subsystems to Technology Readiness Level 5-6 for warfighter use.

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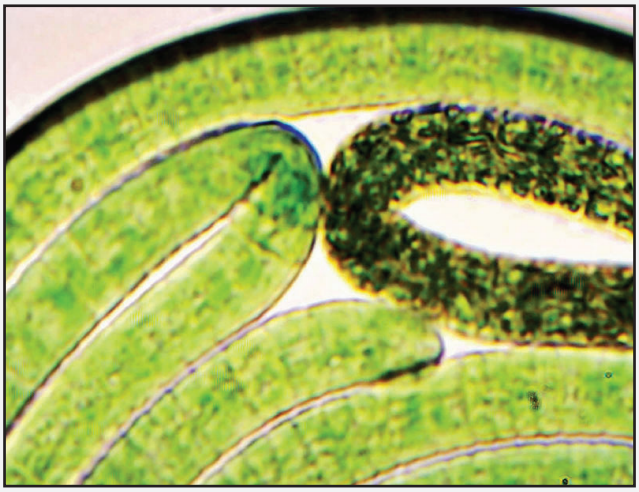
Biofuels Research Could Generate Alternative Energy Source

AFRL-funded biofuels researchers are investigating ways to produce sizable amounts of hydrogen gas using photosynthetic microbes, known more commonly as algae and cyanobacteria. If available in sufficiently large quantities, hydrogen gas could function as a clean, renewable, less expensive energy source for future military systems.

Princeton University's Dr. Charles Dismukes leads the program effort, which is being carried out by a group of researchers from eight different colleges and universities—a group collectively known as the BioSolarH2 team. AFRL funds the BioSolarH2 team as part of the Multidisciplinary University Research Initiative, which focuses on research efforts that combine traditional science and engineering disciplines to address issues of importance to the Department of Defense.

The purpose of the BioSolarH2 team's research is to screen, study, and genetically engineer microbes capable of using light energy to split water molecules and produce hydrogen in the presence of oxygen. During its screening process, the BioSolarH2 team looks for naturally occurring, photosynthetic microbes having hydrogen-generating enzymes, or hydrogenases, that demonstrate a tolerance to oxygen. The team has identified several good candidate microbes in samples collected from the volcanic soda lakes of East Africa's Rift Valley, from Utah's Great Salt Lake, and from various locations throughout Yellowstone National Park.

The researchers' next step is to study the metabolic pathways, or series of chemical reactions, that take place in the microbes to produce hydrogen gas. To facilitate this activity, they developed powerful fluorescent and electrochemical tools and bioreactors for measuring the products and intermediate steps of these chemical reactions.



A picture of Arthrospira maxima, a cyanobacteria

In addition to exploring the microbes' inherent properties and biochemical behavior, the BioSolarH2 team is employing a number of strategies to manipulate the microbes' naturally occurring chemical reactions and thereby increase their hydrogen production. One approach involves applying environmental stresses, such as osmotic shock via salt dilution, to accelerate the slow fermentation process so that it better matches the daily cycle of the sun. This strategy induces the microbes' production of hydrogen at a rate 20 times higher than normal.

Air Force officials anticipate that applications stemming from this research may eventually include biomimetic models for engineering synthetic generators. Capable of producing molecular hydrogen from water and light, these generators would enable the production of clean, renewable, lower-cost energy that could, in turn, lessen the dependence on fossil fuels.

Atmospheric Reentry Experiments Fly Aboard Russian Spacecraft

Close-up view of a holder and material sample after touchdown

AFRL teamed with industry to evaluate a new ground-based approach for simulated atmospheric reentry testing. The method, known as arc jet testing, simulates reentry by exposing materials to an extremely hot plasma flow. This exposure occurs via real-world experiments fitted to a spacecraft—in this case, a Russian spacecraft heat shield—placed into orbit for subsequent reentry observation. After selecting four specially designed material sample holders, the researchers worked within a narrow margin of opportunity to obtain the approvals necessary for shipping the holders and samples to Russia. There, they were mounted on an unmanned space capsule and launched into orbit, later to endure the rigors of atmospheric reentry. All materials provided for the experiments, which flew at no cost to the US, were returned to the team for examination.

AFRL provided the European Space Agency (ESA) with the holders needed to recover arc-jet-tested material samples for comparison purposes. Arc jet testing, which simulates atmospheric reentry conditions by exposing a sample to a directed plasma flow, plays a vital role in the advancement of space technology. Each holder supplied for this effort varied in terms of its material composition. This enabled the research team to test every holder's individual performance during reentry, as well as its potential utility for future heat-shield-mounted experiments.

The actual material samples provided by AFRL flew as part of two ESA experiments: Stone-6 and Lithopanspermia. Stone-6 studies the physical, chemical, and biological modifications that rocks coated with microorganisms (cyanobacteria) or containing fossil microorganisms undergo as a direct result of extreme reentry temperatures and pressures. Lithopanspermia is dedicated to testing hypotheses related to the interplanetary transport of microorganisms (lichen) via meteorites.

The Stone-6 experiments flown aboard Russia's Foton-M3 spacecraft consisted of three rock samples: cemented rock, basalt, and laminate. The Lithopanspermia experiment used granite. Each separate lab-supplied holder housed a different rock sample and its resident living organisms. These four sample holders and their respective contents were attached to the Foton-M3 space capsule's heat shield. Results indicated that the organisms did not survive and, further, that one of the four holders was lost during reentry. The three remaining units, however, proved more durable for reentry than have the holders used by ESA and the Russian Federal Space Agency, ROSCOSMOS, for previous flights.

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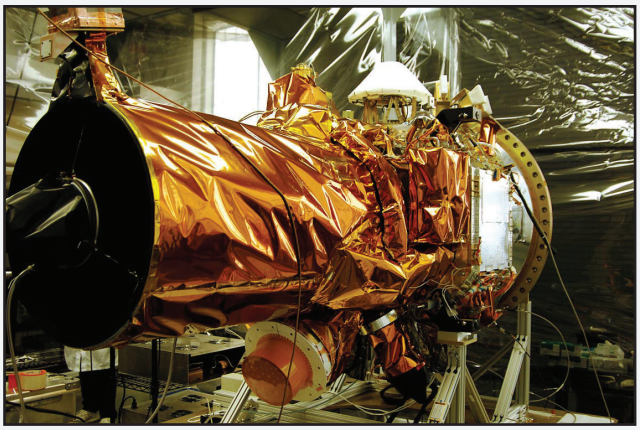
First Fully Compatible Satellite Data Model Flight Software Released for AFRL's PnPSat

AFRL contractor Real-Time Innovations, Inc. (RTI), released the first version of Satellite Data Model (SDM) flight software to be fully compatible with AFRL's plug-and-play satellite (PnPSat). The company's next-generation SDM flight software provides AFRL greater flexibility and consistency in developing plug-and-play avionics, both for ongoing PnPSat research activities and for toolset build efforts in the Responsive Space Test Bed.

RTI engineers based the newly updated software, which is synchronized with the earlier version, on the company's data distribution service approach. The enhancement required no changes to the SDM applications programming interface, nor did it alter the operation of existing applications. For implementation test purposes, researchers ran the modified software on Utah State University's existing test suite using sample code. Another software package (also developed commercially) enables generation of internal documentation from the code itself.



AFRL's PnPSat attached to TacSat-2

For more information contact
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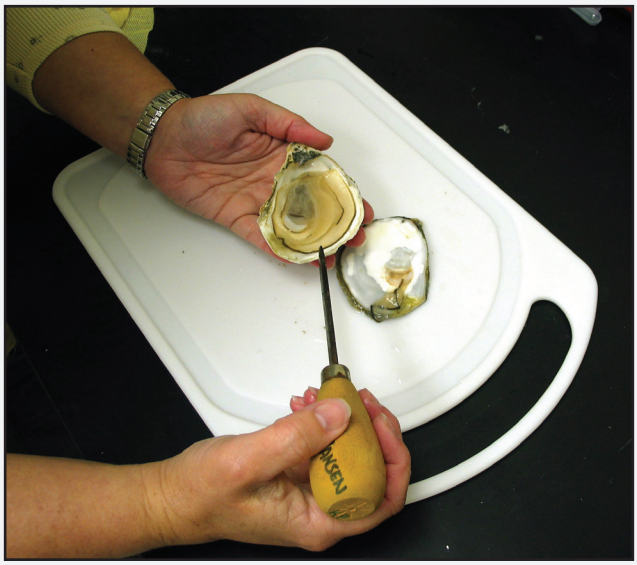
Oysters Used for Developing Pearl-Like Aircraft Coating



Oyster

AFRL is funding University of Dayton Research Institute (UDRI) scientists who are conducting biomimetic research that could lead to new lightweight, durable aircraft coatings. UDRI senior research scientists Mr. Doug Hansen and Mrs. Karolyn Hansen are investigating oyster shell and pearl formation processes. By manipulating these naturally occurring phenomena, the two are working towards a method for depositing pearl-like coatings onto various metal surfaces in order to protect against impact and corrosion damage.

This project is significant because deposition of the biologically derived ceramic coatings does not involve the high-temperature, high-pressure environment required by existing ceramic deposition methods. The Air Force currently uses protective ceramic aircraft coatings for various purposes; therefore, a nonhazardous process for creating ceramics at room temperature and pressure would provide an interesting, potentially better, alternative to current methods.

The UDRI scientists are building on the recent discovery that oysters use blood cells to deposit the crystals that subsequently form shell and pearl. The researchers have targeted these blood cells, manipulating them to deposit crystals on a variety of metal surfaces in an ordered manner that ultimately produces a multilayer ceramic coating.

The goal of the program is to understand the process(es) by which the oyster cells first form these crystals and then deposit them into layers. The scientists hope to achieve a high level of control over the resultant ceramic coating's thickness and placement on materials requiring strong but lightweight protection. In the laboratory environment, live oysters demonstrate ceramic deposition both inside and outside of their shell. Small pieces of metal inserted into the oysters trigger the formation of pearl. Meanwhile, blood cells extracted from the oysters and subsequently placed on metal behave as though they are growing a shell on the metal surface.

The scientists were able to deposit multilayer coatings on four different metal surfaces: two aircraft aluminum alloys and two biomedical alloys. They are currently working to characterize the biomimetic coatings in terms of corrosion resistance, strength, and adhesion. Further, they are developing methods for directing the application of ceramic films at specific sites on metal surfaces.

This research could generate a better understanding of how biological systems can formulate ceramic coatings and films. Such knowledge could facilitate the development of synthetic processes for depositing ceramic films and coatings without the necessity for high-temperature and high-pressure conditions.

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Ghost-Imaging Technology Could Have Satellite Application

AFRL-funded investigators from the University of Maryland, Baltimore Campus are conducting research under the name of "ghost imaging," wherein a visual image of an object is created by means of light that has never interacted with the object. The emerging technology may eventually result in the more versatile use of field sensors, and could have space utility as well.

It was in 1995 that University of Maryland Professor Yanhua Shih initiated what would become known as ghost-imaging research. The focus of Dr. Shih's effort was the use of entangled photons. During his experimentation, one photon passed through stenciled patterns in a mask to trigger a detector, while another photon was captured by a second detector. Surprisingly, an image of the pattern appeared between the two detectors, a phenomenon the physics community promptly labeled "ghost imaging."

In an article entitled "Reflection of a Ghost," published in the April 2008 edition of *Physical Review*, fellow researcher Dr. Keith Deacon alludes to the promise that ghost imaging holds for future application to satellite technology. Specifically, ghost imaging may enable satellites to be equipped with a detector that, when coupled with a second camera, could take images of the sun. Further, this same type of configuration could generate ghost images of the earth's surface during even the most inclement (i.e., obstructive) atmospheric conditions.

Dr. Shih worked with two cohorts from the US Army Research Laboratory, Drs. Ron Meyers and Keith Deacon, in producing ghost images using thermal light. The three scientists combined signals from two detectors—one of which that collected light reflected from a toy soldier and the other that took a digital picture of the light source used for the experiment.

Ghost imaging refers to visual object imagery created via light that does not interact with the object. The technology may enable increased sensor versatility and new space applications (image courtesy of the University of Maryland).

The mechanics of ghost imaging are similar, though not identical, to those involved in flash photography. In snapping a flash-lit photo using a normal camera, the image forms as a result of photons emitted from the flash, bounced off the object, and focused through the camera lens onto photoreactive film or a charge-coupled array. Conversely, ghost images do not form as a result of light (photons) hitting an object and bouncing back. Instead, the camera captures photons emitted from sources of light that did not hit the object and then paired (through a quantum effect) with photons from light that did. The ghost image begins to appear once the camera has recorded approximately 1,000 photon pairs in this manner.

C/NOFS Technology Launches on Satellite

AFRL-developed C/NOFS

The AFRL-developed Communication/Navigation Outage Forecasting System (C/NOFS) launched aboard a satellite platform as part of a joint effort with the Air Force Space and Missile Systems Center (SMC). The technology is aimed at helping the Department of Defense (DoD) better understand and forecast the impacts of ionospheric scintillation on communication and navigation systems.

AFRL worked in conjunction with various government and industry partners to develop six ionospheric sensors, which were subsequently integrated into the overall system. Each sensor performs a specific task related to collecting data in the ionospheric equatorial region. Collectively, these sensors will aid efforts to analyze and predict the effects of ionospheric scintillation, a naturally occurring phenomenon that causes disruption or degradation of radio waves as they pass through ionospheric plasma.

Leveraging both satellite and ground-based data processing technology, C/NOFS provides the first-ever capabilty to forecast the impacts of ionospheric scintillation on the operational performance of ultra-high-frequency satellite communication and Global Positioning System navigation systems.

SMC and prime contractor General Dynamics built the spacecraft bus and also provided Orbital Sciences Corporation's Pegasus launch vehicle. C/NOFS launched from the Army's Reagan Test Site (Kwajalein Atoll, Marshall Islands).

The C/NOFS program is an advanced concept technology demonstration effort, with AFRL functioning as the technical manager, Air Force Space Command as the transition and operational manager, and US Strategic Command as the user sponsor.

AFRL and its government and contractor teams will use the data collected by C/NOFS sensors to create physics models that will, in turn, assist scientists in identifying and forecasting conditions conducive to ionospheric scintillation. The research team will also disseminate C/NOFS data and resultant products for use by various DoD organizations.

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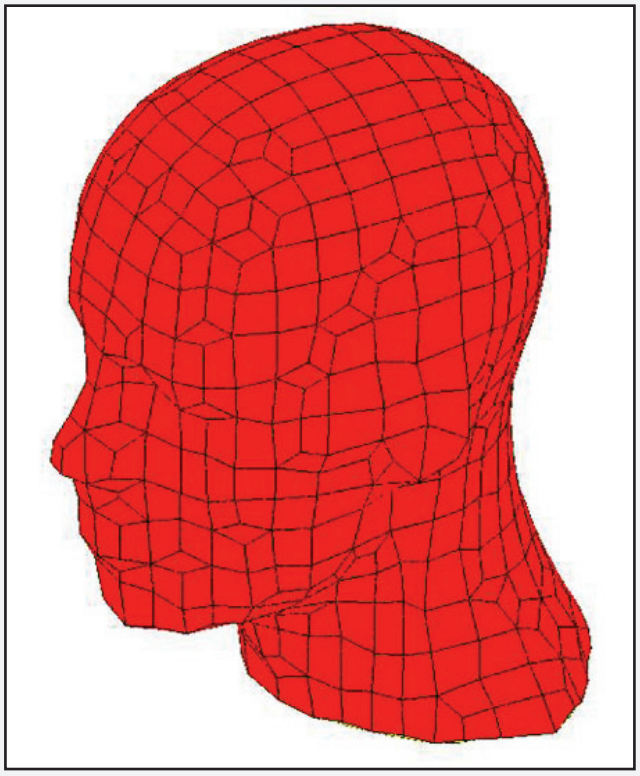
Model Developed to Aid Research of High-Noise-Environment Hearing Protection

Researchers funded by the Air Force, Army, and Navy are investigating ways to improve communication links for people wearing headphones, helmets, and other protective equipment in noisy environments. Their research has been an especially important collaboration for the military, because many serving in the armed forces suffer from hearing impairment due to repeated exposure to aircraft engine sounds and large-caliber weaponry.

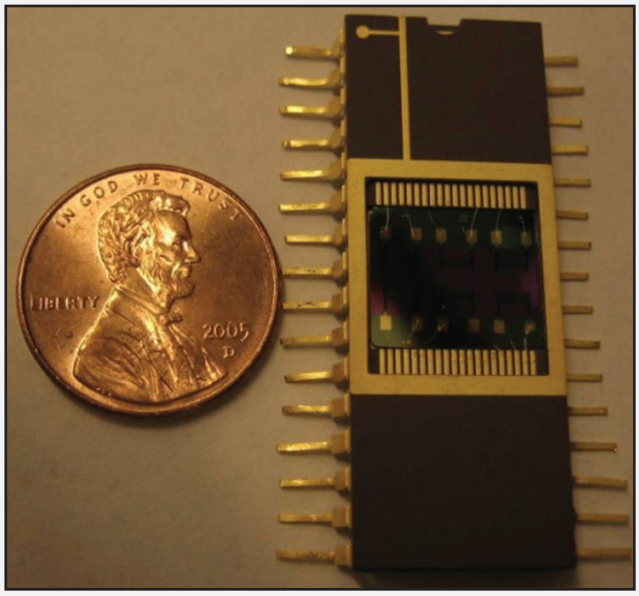
Dr. Leszek Demkowicz is a University of Texas at Austin scientist whose expertise lies in constructing geometric models and corresponding finite-element code. He is working alongside other scientists who specialize in finite elements, geometry description, acoustics, and hearing science to conduct research about high-noise environments. Despite lacking a fundamental research base regarding the transmission of acoustic energy through nonairborne pathways to the cochlea, the researchers have persevered. They turned to earlier software tools as a basis for creating finite element code that, in turn, helped them build a model of the human head. The model details the cochlear region and its interface with the skull and air pathways. To fully leverage the finite-element code requires a mathematical description of acoustical wave movement through the model.

Because significant amounts of acoustic energy can reach the cochlea via nonairborne pathways, earmuffs, earplugs, and other ordinary hearing protection devices are rendered ineffective in its presence. Acoustic energy can consequently interfere with and degrade one's ability to localize the directions of sound sources and, further, can impede voice communications. This effort to examine hearing protection in high-noise environments is built upon two decades of research on higher-order finite elements for wave propagation problems, as documented by Dr. Demkowicz in his two-volume book, *Computing with hp-Adaptive Finite Elements*, and addressed in over 45 additional publications as well.



Finite element code created by leveraging earlier software helped researchers build a model of the human head. This graphical representation mirrors the actual model in detailing the cochlear region and its interface with the skull and air pathways (US Air Force graphic).

Researchers Develop Coin-Sized Bomb Detection Sensor



Penny-sized sensor that detects bombs made with improvised peroxide explosive devices

An AFRL-sponsored research team from the University of California at San Diego (UCSD) created an inexpensive sensor that detects bombs made with improvised peroxide explosive devices. Earlier detection devices with similar characteristics were large and expensive, whereas the new sensor is the size of a penny and costs less than a dollar per device. UCSD has applied for a patent on the ultrathin sensor but awaits finalization regarding its licensing. Meanwhile, the new sensor has attracted the interest of potential licensing partners who favor its size, cost, and possible use in commercial applications.

Drs. William Trogler, Andrew Kummel, and Ivan Schuller created the small sensor using ultrathin films composed of cobalt and copper, metals providing both the fast response time and the necessary sensitivity for detecting even minute amounts of peroxide vapors. The presence of peroxide in the environment causes the cobalt-based films to show a reduction in current, while the copper films reflect an increase.

The low-power micro and nanosensors are ideally suited for small and micro unmanned air vehicle platforms, which can use the technology for remote sensing operations geared towards protecting personnel and facilities from chemical warfare agents.

The team's chief challenge is to extend the array sensing approach to broader applications. Doing so will require the researchers to conduct further basic research towards understanding and controlling the interaction between the central metal ions in the sensor materials and the agents, toxins, and fuels encountered. Preliminary work with a sensing algorithm shows promise in yielding test results from an array, and the UCSD team hopes to develop this into a practical microsensing array platform for detecting a wide range of agents, toxins, and fuels, as well as specific manufactured odors.

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Virtual Reality Project Could Improve UAV Operations

An AFRL-managed team led by Dr. James Oliver, leading researcher from Iowa State University, is busy constructing a virtual reality environment in support of the battlespace initiative towards maximizing unmanned air vehicle (UAV) potential. The team's work involves the application of advanced physical and eye-tracking systems and voice interfaces. The goal of this ongoing effort is to provide role-specific interfaces, along with shared situational awareness, for a team via a large audiovisual display.

As part of its initial focus, the team is addressing significant human interface issues arising from the limitations that affect operators who control UAVs from the ground. Accordingly, the researchers are designing and testing the hardware, software, and aeronautical systems needed for creating immersive ground control stations based on virtual reality technology. They are also developing and measuring the effectiveness of new human interface techniques that will enable operators to effectively control multiple semiautonomous aircraft. Already, the system can accommodate the simultaneous participation of 230 interfacing users.

A virtual battleground, complete with the multiple and varied information sources available in an actual modern military engagement, serves as the primary interface context for users of this manufactured environment. Housed and delivered inside a three-dimensional audiovisual stereoscopic facility, the virtual reality technology comprises 6 walls, 24 projectors, an ultrasonic motion tracking device, a means for 8-channel audio, and a single graphics computer. The selected delivery context has many benefits, including large-field-of-view coverage and innovative information representation.

To further the maximum potential of UAVs, an AFRL-managed research team is building a battlespace environment based on virtual reality technology (photo courtesy of Iowa State University).

The virtual reality environment will enable participants to see not only the vehicles, surrounding airspace, and terrain over which they are flying, but also the information collected from instruments, cameras, radar, and weapons systems. This approach has the potential to overcome the critical training and operational challenges related to simultaneous monitoring and control of multiple UAVs concurrently. The team is also exploring new ways to employ virtual reality to address the problem of time lag, which is characteristic of applications involving machines operated at a distance.

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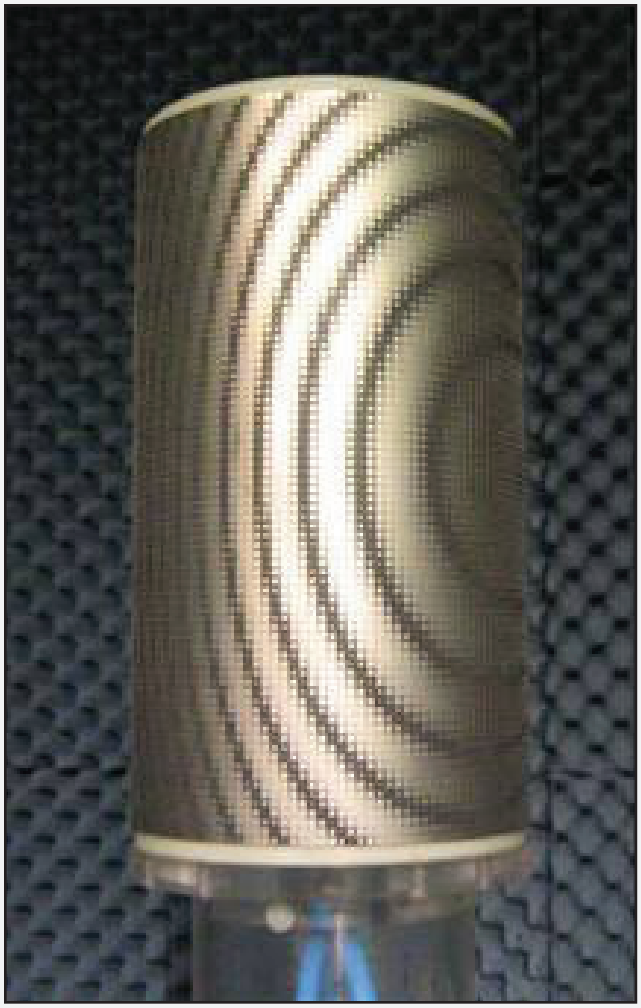
Advances in Holographic Impedance Surfaces for Antennas



Holographic impedance surface (graphic courtesy of Dr. Daniel F. Sievenpiper, HRL Laboratories)

AFRL-funded researchers at HRL Laboratories, LLC, are working to develop holographic impedance surfaces for antennas, a capability that will enhance aircraft aerodynamics and antenna (i.e., radar) performance alike. The team of industry scientists, led by Dr. Daniel F. Sievenpiper, is employing an electromagnetic design technique similar to that used for creating holograms. The novel technology opens the door to the use of antennas that, while completely flush with the aircraft's aerodynamic surface, exhibit performance equal to—or surpassing—that of devices based on conventional design methods.

To build the holographic impedance surfaces, Dr. Sievenpiper and his team are using metallic materials on a substrate. The resulting structures perform comparably to objects covered with the surface impedance, highlighting yet another prospective benefit of the technology. Specifically, if an aircraft tail obstructs an antenna beam but that tail is covered by a suitably crafted impedance surface, the beam will "flow" around the tail as though it were not there. Along with underscoring these promising advantages, the HRL Laboratories team is exploring ways to further extend electromagnetic impedance technology, including its practical implementation. The scientists plan not only to create new kinds of unit cells, but to pursue new mapping techniques enabling those cells to be positioned over complex objects. Accordingly, the team will continue to leverage a variety of simulations, large-scale electromagnetic calculations, and measurements.

Dr. Sievenpiper received the International Union of Radio Science Isaac Koga Gold Medal for his participation in this ongoing work. The award, which honors the outstanding contributions of scientists under the age of 35, acknowledges his efforts towards the development of artificial impedance surfaces and conformal antennas. Specifically, the award recognizes a range of achievements, spanning Dr. Sievenpiper's early development of artificial magnetic conductors while attending the University of California at Los Angeles as a graduate student through his more recent involvement in developing tunable and holographic impedance surfaces at HRL Laboratories.

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Intuitive Battlefield Technology Connects Warfighters

AFRL engineers responded quickly to an Air Force joint terminal attack controller (JTAC) challenge to solve a nagging combat problem related to directing air strikes against enemy positions. They developed and delivered a simple, lightweight, user-friendly cable enabling the transfer of critical target location data from a laser range finder to a personal computer (PC) for processing. AFRL's prototype entails a cable that is not only slimmer and lighter than its predecessor, but also more efficient and easier to use in the field. More importantly, the human-centered design cuts precious seconds off the time needed to establish a connection between handheld Mark VII laser range finders and wearable laptop PCs. For JTAC personnel in the midst of controlling precision air attacks against enemy targets located near friendly troops, every second counts and efficiency is vital to mission success.

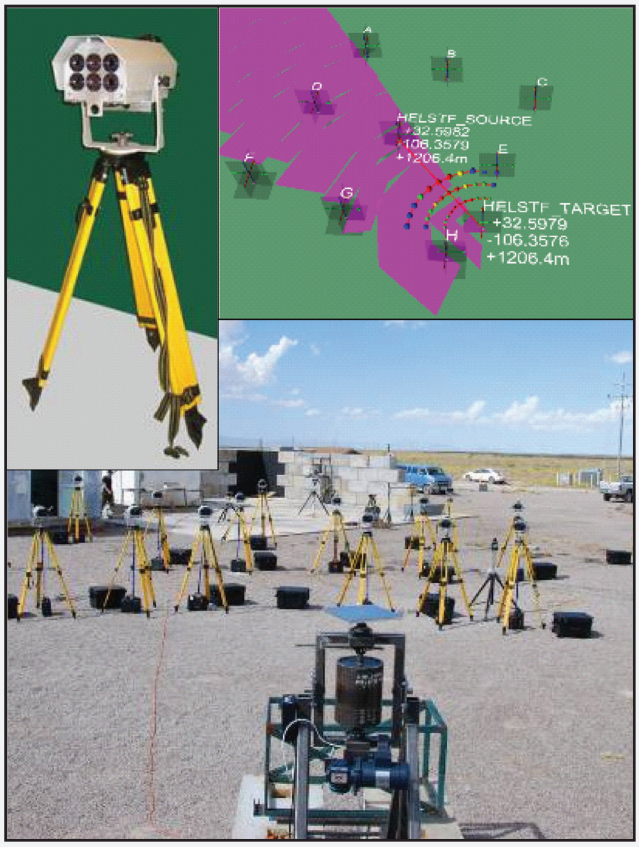
AFRL engineers responded rapidly to the cable request, using existing funds available under the Battlefield Air Targeting Man-Aided kNowledge (BATMAN) program. A goal of the BATMAN program is to continuously review and improve battlefield technology in order to make warfighters more effective.

The engineering team designed the new cable, fabricated the prototype, and conducted in-house testing of the product. They named their product Grabs-M, a moniker describing the cable's capacity to "grab" only that digital data which is required (i.e., pertinent to the operation). Upon establishing the prototype design, the engineers turned to Future Technology Devices International, Ltd. (FTDI), a United Kingdom–based manufacturer specializing in the conversion of older communications devices to universal serial bus technology. FTDI ruggedized the design for military use and subsequently built the production cables. The company now lists the item as a product available for direct purchase.

AFRL project engineer Greg Burnett (left) demonstrates the user-friendly Grabs-M cable, the design of which enables combat controllers to quickly and efficiently transfer digital coordinates from a laser range finder to a computer in the field (photo by AFRL's Chris Gulliford).

At just 7 ft long, Grabs-M is half the length of the older cable. It is also 75% lighter and takes up to 59% less space, important factors for JTACs, who may carry up to 150 lbs of gear into the battlefield. In addition, cable length is simple to adjust, and damaged cables are easily repaired. There are also significant cost savings; Air Force Special Operations Command pays approximately $17 for one new Grabs-M cable, compared to the $500-$1,000 price tag of cables providing similar functionality.

AFRL Supports Triservice Acquisition of TREM Capability



TREM

The triservice Directed Energy Test and Evaluation Capability (DETEC) program identified a dozen critical test and evaluation infrastructure needs for laser and radio frequency systems. Among the program's highest priorities was the procurement of a target reflected energy measurement (TREM) capability. Used for quantifying the amount of laser energy reflected and scattered during a high-energy laser (HEL) target engagement, TREM enables characterization of both radiometrics and collateral hazards.

Throughout the 2-year acquisition program, AFRL scientists and engineers (S&E) supplied subject-matter expertise and documentation supporting the analysis of various alternatives; they also provided modeling data that ultimately led to a requirements definition for the TREM system. As part of their analysis focus, the S&Es identified AFRL's Laser Range Safety Tool (LRST)—an existing model used for HEL target radiometric predictions—as a possible means for achieving test planning and layout, and at significant cost savings. The AFRL team successfully met TREM test planning requirements through a subsequent 8-month technical effort geared towards modifying the LRST code for use in TREM acceptance tests.

The decision to leverage AFRL's LRST saved the DETEC program nearly $2 million in software development costs. AFRL personnel continued to play a key role during full-scale TREM acceptance testing, conducted over a 2-week period. Specifically, the team provided critical assistance in the areas of test planning and safety support, beam delivery optics and diagnostics, and sensor setup and data download (including data downloaded from independent radiometric sensors, which underwent cross-check against TREM data for validation purposes).

The team analyzed over 900 sets of laser target reflection/scatter data collected during the 2-week field test. Test results indicated satisfactory system performance in the acquisition of reflection/scatter data under a variety of exposure conditions. The TREM capability now stands ready to support directed energy weapons testing for the Department of Defense, and test planning is under way to support high-profile efforts such as the Advanced Tactical Laser.

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Research Confirms Safety Standards for RF Devices

In the 1990s, researchers affiliated with the University of Lund, Sweden, conducted basic research seemingly refuting safety standards governing radio frequency (RF) emissions. The study indicated that RF radiation emitted at cell phone frequencies and power densities below levels considered safe nonetheless posed a human health hazard. Specifically, the results showed that the low-dose emissions caused large proteins to leak across the blood-brain barrier, a semipermeable membrane that protects the brain from foreign substances in the blood. Consequently, AFRL began leading an international consortium of laboratories in an effort to replicate the Swedish studies and determine if the effects were real. With the AFRL-led studies now complete, the US, French, and Japanese laboratories involved in the effort have failed to produce the same effects as the Swedish labs, effectively confirming the validity of current RF safety standards.

Possible explanations for the Swedish results include errors in RF dosimetry, stress on test subjects, and artifacts in the histological staining processes used for postexposure evaluation. Based on the more recent results, the scientifically accepted view holds that blood-brain barrier leakage does not occur with exposure below established safe levels. The AFRL-led research thus validates current RF safety standards, maintains confidence in RF weapon system effectiveness, and negates the need for extensive and costly changes to military RF devices such as radars, radios, and telephones.

Blood-brain barrier leakage, which can cause the brain's temperature to increase to 42°C or 43°C, is scientifically proven to occur with much higher RF exposure levels. However, lower power densities have no historical association with this harmful phenomenon. Scientists acknowledge that the accuracy of RF bioeffects research is susceptible to the influence of artifacts in the process. This vulnerability arises not only from the complicated nature of RF research equipment, but from the unavoidable variability of the stress response exhibited by different biological organisms. In such studies, therefore, it is not unusual for effects to appear that are later proven to be the result of experimental error. Unchallenged scientific acceptance of the Swedish study would have prompted unnecessary lowering of acceptable RF exposures as defined in standards established by the Institute of Electrical and Electronics Engineers and the International Commission on Non-Ionizing Radiation Protection. In turn, the falsely lowered emissions threshold would have needlessly increased keep-out zones, limited the use of US military RF devices in Europe, and otherwise negatively affected Department of Defense operations and commercial RF applications alike.

Scientists conduct RF radiation tests at cell phone frequencies and power densities.

For more information contact
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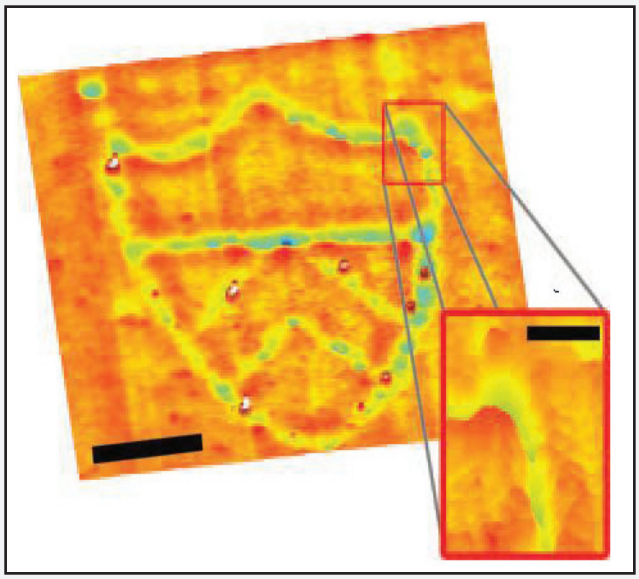
New Nanopatterning Method Impacts AF Needs of Today and Tomorrow



New direct-write approach to optical nanopatterning (image courtesy of Dr. Craig Arnold)

Princeton University professor and AFRL-funded researcher Dr. Craig Arnold is investigating a new approach to optical nanopatterning, the process of forming nanometer-scale patterns on a substrate. Standard nanopatterning creates highly precise patterns in controlled, clean, and vibration-free environments. Consequently, many traditional Department of Defense and AFRL technologies rely on it for applications involving microelectronics, space-based or other remote platforms, small-scale development, and even large-scale aircraft and munitions. A new direct-write approach for leveraging this important patterning capability will thus impact a variety of current and future Air Force (AF) needs.

The properties inherent to nanomaterials afford researchers the opportunity to work with substances—namely, low-temperature, non-vacuum-compatible, and flexible substrates—that are traditionally difficult to pattern. Dr. Arnold's research team performed all tests associated with this effort in an office environment, on an optical bench with no vibration control. In an AF context, the simplicity of this test environment implies that it may be possible to implement the emergent technique to repair and modify materials in the field, and possibly even aboard moving aircraft.

Researchers used optical tweezers to manipulate beads about the substrate surface,firing a high-power, pulsed ultraviolet laser in any location requiring modification beneath a given bead. Importantly, test results indicate that this method accommodates parallel nanopatterning on all kinds of surfaces. Further, the approach eliminates the major drawbacks of conventional laser-based patterning techniques, such as slow speed and substrate damage, while achieving higher resolution.

For more information contact
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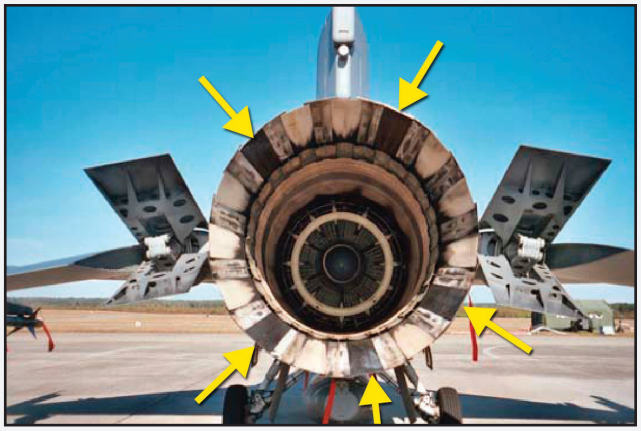
Ceramic Matrix Composite Seals Proving Reliable for Jet Engine Nozzles

AFRL engineers are working with industry partners to test the use of ceramic matrix composite (CMC) materials as divergent seals in F100-PW-229 gas turbine engine exhaust nozzles. Geared towards increasing part life, improving reliability, and reducing operating and maintenance costs, the research is focusing on SEPCARBINOX® A500, an advanced self-sealing CMC manufactured by French company Snecma Propulsion Solide (SPS). Thus far, the seals have performed extremely well, and a life-cycle cost analysis is under way to determine whether they should be introduced into the fleet as preferred spares. CMCs are excellent candidates for replacing the nickel-based superalloys currently used in exhaust nozzle parts, primarily due to their capacity to withstand the high temperatures and severe operational environment for much longer periods of time with minimal changes in structural behavior.

In examining the feasibility of using the A500 seals on the divergent section of the exhaust nozzles, AFRL researchers are addressing a number of key Air Force issues—one of which involves the performance comparison of CMC parts in flight and during engine ground testing. SPS has developed a novel CMC that uses carbon fibers in a sequentially layered carbide matrix produced via chemical vapor infiltration. Because this resultant matrix is self-sealing, it helps protect the carbon fibers from oxidation. The fibers are woven in a multidimensional, ply-to-ply angle interlock pattern to reduce the chance of delamination.

Researchers completed extensive ground tests simulating the part's full, 2,000-flight-hour life cycle on one CMC seal. Measurements indicating the retained tensile strength of



An F-16 Fighting Falcon F100 engine exhaust nozzle with five A500 CMC divergent seals, identified by the yellow arrows (US Air Force photo)

the ground-tested seal verified the excellent mechanical durability of the CMC hardware. The part was in "like new" condition, with no measurable degradation. The successful results obtained from ground testing prompted the start of a field service evaluation for assessing the seal hardware on operational aircraft. Researchers subsequently removed and evaluated an A500 seal having 350 flight hours. The seal underwent visual inspection, as well as thermography-based damage checkout. Despite its 17-month service life and associated flight hours, the seal showed no signs of surface erosion, wear, or degradation. The seal's appearance was essentially identical to its as-produced condition. Tension tests conducted on this same seal demonstrated that its properties of retained tensile strength were equal to or higher than stored database values delineating this performance measure.

Air Force Considers Applications of Jamming Model

Tribo-rheometer

Granular solids (e.g., salt or sand) and viscous liquids (e.g., toothpaste or wood glue) can behave like solids or liquids, depending on conditions. When these fragile-state materials stop flowing, scientists refer to the transition from fluidity as "jamming." With funding from AFRL, Dr. Pirouz Kavehpour and his team of researchers at the University of California at Los Angeles (UCLA), Henry Samueli School of Engineering and Applied Science, are investigating this phenomenon. As part of their effort, they formulated a thermodynamic model for predicting jamming behaviors in fragile materials. They also developed a Tribo-rheometer system to test the predictive capacity of their theoretical model.

Air Force (AF) officials are interested in what beneficial effects the team's model could bring to the development of new materials enhancing Department of Defense systems. Such prospective materials could range from a new family of lubricants for extreme-environment applications to a new generation of impact-resistant shields.

Fragile materials share common jamming behaviors, but until now, researchers have been unable to establish a common mechanism among the different material types. In devising a thermodynamic approach, the UCLA researchers have discovered a means of predicting the jamming behavior of numerous materials using a single model.

The team began by using an existing model to focus on the behavior of dry sand, introducing a nonthermal temperature in order to measure the fluffiness of the granular material. The temperature variable also made sense for the team's subsequent study of viscous liquids, which become resistant to flow when cooled.

The researchers plan to use their model for various applications in commercial and defense industries alike. Currently, the team is working with AFRL to examine the characteristics of a new family of strong, durable materials with potential applications of interest to the AF.

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Carbon-Carbon Rapid Densification Process Improves Rocket Exit Cone Materials

AFRL engineers developed an *in situ* carbon-carbon rapid densification method that has since been applied for the first time to an EM-76 solid rocket exit cone. ATK Launch Systems initially rigidized the exit cone with phenolic. Allcomp, Inc., was then able to use the AFRL-developed process to further densify the cone to aerospace quality in just 5 days. AFRL's *in situ* process not only takes just 20% of the time that current state-of-the-art methods require, but also saves costs throughout the manufacturing cycle. As a result of this breakthrough, engineers now have an improved materials capability available to consider for applications that are presently reliant on traditional materials.

As a result of concerns involving cost, schedule, and manufacturability, the aerospace industry has employed carbon-carbon technology sparingly for many years. AFRL's new *in situ* rapid densification process increases the viability of using carbon-carbon composites for propulsion systems and other potential applications. Future plans include a test-fire demonstration for evaluating the process-enhanced exit cone's performance.

Rocket exit cone

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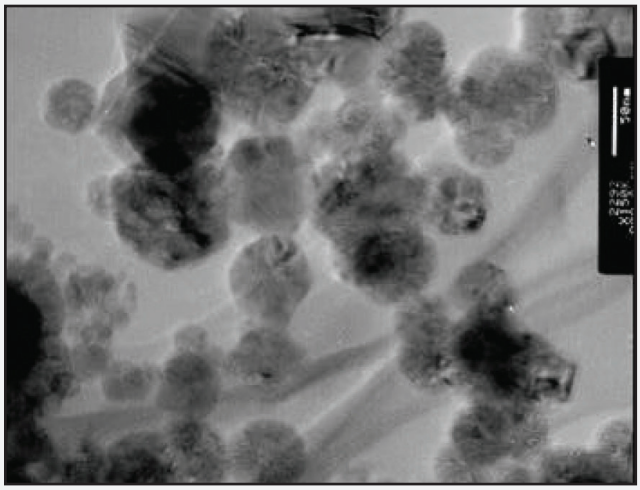
Energy Research Could Cut Costs and Increase Efficiency



Fusing nanoparticles (image courtesy of Drs. Ronggui Yang, Zhifeng Ren, and Gang Chen)

An AFRL-funded mechanical engineer developed an inexpensive, efficient material that will enable electronic devices to quietly and motionlessly self-regulate temperature and convert excess heat into a power source. This new development could impact the energy sector, given that high cost and low efficiency have heretofore precluded widespread use of conventional thermoelectric materials in converting thermal energy into electricity. Broader military and commercial applications, ranging from self-powered sensors to refrigeration and more fuel-efficient cars, may eventually be possible.

Dr. Ronggui Yang's method, developed with his colleagues at the University of Colorado at Boulder, involves the fusion of nanoparticles and nanowires to create a composite material. The use of nanoscale components helps to slow heat flow, which improves the material's capacity to convert thermal energy into electricity. The nanocomposite material resulting from Dr. Yang's efforts not only performs well in tests, but can also be mass-produced at low cost.

An important aspect of Dr. Yang's success was his decision to collaborate with experts in other disciplines in order to leverage advances in areas such as computation, physics, and materials science. His researchers are using quantum mechanics simulation to learn how electrons behave in nanostructures and are likewise employing topology optimization, coupled with statistical mechanics simulation, to design thermal nanostructures.

Dr. Yang has devoted considerable effort to understanding the fundamentals of thermoelectric materials, which allows him both to explain his method in relatively simple terms and to react quickly to new design and structural concerns. Particularly interested in integrating this new generation of thermal materials into microscale unmanned air vehicles, AFRL is funding this facet of Dr. Yang's work through a Multidisciplinary University Research Initiative (MURI) grant for the integration of energy harvesting and storage capabilities into load-bearing structures.

In addition to supplying the MURI grant, AFRL supports Dr. Yang through a Discovery Challenge Thrusts program on thermal transport phenomena and scaling laws. Dr. Yang also receives National Science Foundation funding for his design-centered approach to nanoengineering. This breakthrough research earned Dr. Yang a spot in *Technology Review* [TR] magazine's 2008 "TR35," the publication's annual list of 35 outstanding men and women under the age of 35 who exemplify the spirit of innovation in business and technology.

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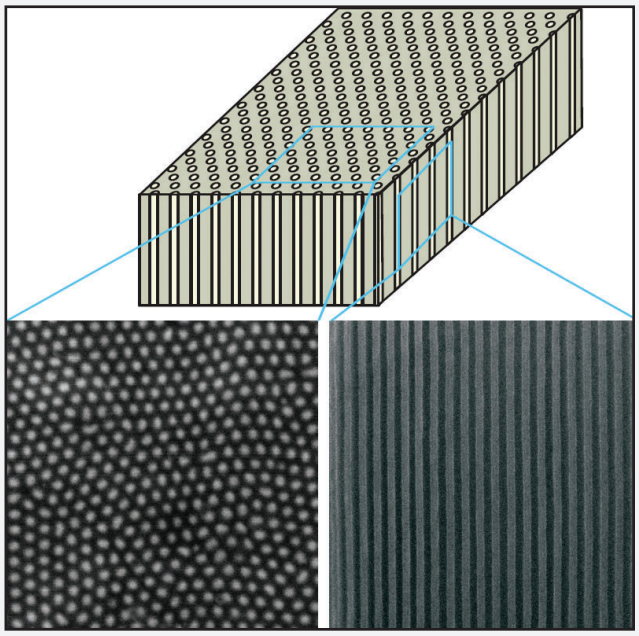
Researchers Compress Light to Advance Optical Communications

AFRL-funded scientists at the University of California at Berkeley (UCB) fabricated a new type of metamaterial that bends light backwards, in a manner not occurring in nature. As a result of compressing light into tighter spaces, the newly developed material enables improved optical communications, computation and detection, and camouflage capabilities. The UCB optics research team, led by mechanical engineering professor Dr. Xiang Zhang, created the metamaterial by embedding metal nanowire arrays in porous aluminum oxide. An article documenting the significance of these work results, entitled "Optical Negative Refraction in Bulk Metamaterials of Nanowires," appears in an August 2008 edition of *Science* magazine.

As part of a bottom-up technique for fabricating the new metamaterial, the team employs electrochemical methods to grow silver nanowires inside the nanopores present in macroscopic-sized aluminum oxide. While this previously invented method is already in use among chemists, the researchers were able to further leverage the special technique to achieve bulk fabrication of the new material—a novel success in its own right. Consequently, their work brings a fresh perspective and heightened feasibility to the metamaterials field.

This same group of scientists earlier proposed a novel waveguide scheme with the capacity not only to pass light through a space 400 times smaller than the width of a human hair, but to confine light within spaces dimensionally no larger than 10 nanometers. The results of this past work, also sponsored by AFRL, were outlined in *Nature Photonics*. Meanwhile, the team is currently directing its metamaterials activity towards subwavelength imaging. Though still in the exploratory phase of this new focus, the researchers anticipate that pursuing a thorough understanding of the innumerable metamaterials applications will yield innovations that significantly impact the Air Force military tasks of today and tomorrow.



AFRL-funded scientists at UCB fabricate metamaterial that compresses light into tighter spaces, improving optical communications, computation and detection, and camouflage capabilities (US Air Force graphic).

Automated Aerial Refueling Positions and Pathways Flight Tests a Success

Automated aerial refueling flight test

Researchers from AFRL and Boeing Phantom Works completed automated aerial refueling (AAR) positions and pathways flight tests. During the series of flights, the research team demonstrated the AAR system's capability to autonomously execute all aerial refueling maneuvers while flying in close formation with a tanker, as well as its capacity to perform practice breakaways. A Calspan Learjet acted as a surrogate unmanned refueling receiver aircraft, using the AAR system to successfully track—via a Boeing-provided flight control computer (FCC) with Northrop Grumman Precision Global Positioning System—the tanker's flight path in order to position itself in a trail formation; fly up to the tanker; and make the necessary adjustments to achieve observation, precontact, and contact refueling positions.

The purpose of the AAR program is to develop the capability to use the existing Air Force tanker fleet for boom and receptacle refueling of unmanned air vehicle systems and to demonstrate this capability using operationally representative subsystems. Researchers were able to validate many AAR technology advancements during these flight tests, wherein a Learjet was manually flown to the transition point behind a Boeing KC-135R (provided by the 107th Air Refueling Wing of the New York Air National Guard). A Boeing flight test engineer (FTE) aboard the Learjet engaged the Boeing-provided FCC and control laws, which subsequently employed relative navigation state data derived from the Precision Global Positioning System solution to autonomously fly the Learjet to the observation position on the tanker wing. The Boeing FTE then used a control station on the Learjet to fly to the precontact and contact positions after receiving approval from the tanker crew. During the flights, the AAR system remained engaged for over 1 hour and 40 minutes and held formation at the contact position for 20 consecutive minutes.

During another test flight, the Learjet followed the Boeing KC-135R through two complete refueling orbits. Throughout the positions and pathways flight test, the Learjet was engaged for over 8 hours near the tanker. In addition to demonstrating the proper flight characteristics for a refueling receiver, the AAR research team continues to make strides towards preparing AAR technology for transition to production systems. By leveraging improved relative navigation algorithms, control laws, and hardware, the team has achieved advances in system integrity, continuity, and availability.

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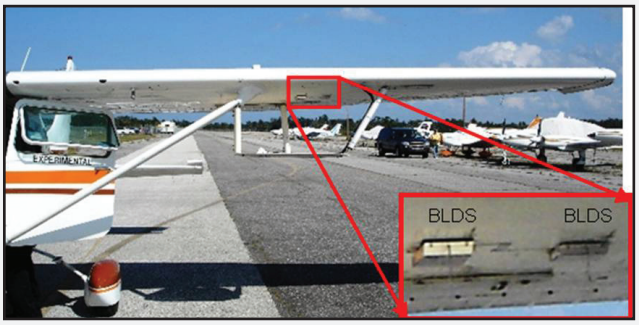
Researchers Test Boundary Layer Data System

AFRL, in conjunction with Northrop Grumman and Washington State University (WSU), completed a series of flights to test the recently developed Boundary Layer Data System (BLDS-A). The BLDS-A is an instrument designed to characterize aircraft boundary layer—the thin layer of air at the surface of the aircraft. In this region, the air flowing over a surface transitions from laminar (smooth) to turbulent. Understanding boundary layer properties is therefore critical to understanding how an aircraft performs, especially in terms of lift and drag. The BLDS-A is a small, lightweight, self contained unit that is easily attached (via removable structural adhesive) to virtually any location on an aircraft surface.

The BLDS-A instrument has built-in power, data acquisition, and data storage capacity, which means there is no need to route pressure tubes or instrumentation wires to the device. The unit's small size enables it to collect accurate in-flight data with no interference to aircraft operations. To test the BLDS-A, researchers attached the device to a Northrop Grumman–owned Cessna TU206 aircraft, which subsequently flew a total of eight sorties wherein the BLDS-A successfully collected boundary layer data. WSU researchers then analyzed the data.



BLDS-A attached to the wing of a test aircraft

In addition to gathering data, the flight test confirmed BLDS-A system functionality. As a result, the instrument will be part of an upcoming SensorCraft wing flight test. The data gathered from the BLDS-A flight tests will help researchers better understand boundary layer behavior on the SensorCraft wing test article mounted underneath the Scaled Composites, LLC, White Knight aircraft. The BLDS-A flight test effort is part of Northrop Grumman's Aerodynamic Efficiency Improvement program, which seeks to develop and test aircraft structural and aerodynamic technologies for future intelligence, surveillance, and reconnaissance vehicles such as the SensorCraft concept.

Lab Tests Potential Space Vehicle Designs

A hypersonic vehicle model undergoes wind tunnel testing.

AFRL researchers recently tested six different hypersonic vehicle configurations to learn about the flight characteristics of potential reusable space vehicles. The series of tests, conducted at the Arnold Engineering Development Center's Hypervelocity Tunnel 9, is part of the High-Alpha Reusable Launch Vehicle (RLV) Aerodynamic Configuration Development program. The purpose of the test effort was to gather data on the different vehicle configurations and validate the computational fluid dynamics (CFD) codes used for predicting airflow around the vehicles.

Of the six vehicle configurations tested, the AFRL High-Speed Configurations team developed five. The remaining test configuration was the Hot Eagle design, developed by Conceptual Research Corporation. All six configurations represent reusable second-stage hypersonic vehicle designs.

Each configuration underwent tests at Mach 14 speeds and 30°-75° angles of attack. Under these test conditions, researchers gathered stability, pressure, and heat flux data for each vehicle design, completing all tests successfully. The results will assist researchers in modifying the computational modeling processes and approaches, as well as identifying the areas in which CFD codes were unable to accurately model the airflow. The data will also assist AFRL's in-house reentry vehicle design studies. Overall, these tests expanded the knowledge base pertaining to hypersonic flight, since existing literature contains no data regarding high angles of attack >50° on complex configurations.

High-alpha RLVs are reusable space access vehicles that could potentially carry payloads into space and return for quick-turnaround reuse, saving time, money, and manpower. These vehicles may also provide benefits in terms of increased reliability and safety.

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Flight Tests Examine Latest Sense and Avoid Technology

Engineers from AFRL, Northrop Grumman, and Calspan Flight Research collaborated to complete the latest in a series of flights geared towards testing autonomous airspace deconfliction capabilities for unmanned aircraft systems (UAS). The multiple-intruder autonomous avoidance (MIAA) testing took place at Calspan facilities at Niagara International Airport, New York. The goal of this particular flight series was to record data from the multiple, dissimilar sensors embedded in the test aircraft's overall Sense and Avoid (SAA) system. In addition to incorporating these sensors, the UAS SAA system includes three electro-optical (EO) cameras, a low-power radar coupled with decision logic and autonomous maneuvering capabilities, and Traffic Collision Avoidance System (TCAS) technology. The SAA system also has the built-in capacity for automatic dependent surveillance broadcasting, which enables its detection and avoidance of similarly equipped aircraft.

Currently, UAS lack autonomous airspace deconfliction capabilities, a shortcoming that prevents these aircraft from operating freely in national and international airspace. The goal of the SAA system team is to equip UAS with the technology needed for performing autonomous airspace deconfliction—one of several necessary steps towards achieving airspace integration. Among the aircraft that could benefit from SAA technology are the Global Hawk and Predator UAS. The recent flight tests included head-on, crossing, ascending, overtaking, and descending encounters. Also flown during the series were trail formation flights wherein various levels of background clutter (e.g., clouds, ground, and water) and obscuration (e.g., rain and haze) were present. The EO, radar, and TCAS data recorded during these tests will assist further refinement of system sensors, as well as evaluation of the SAA target-correlation algorithms. The information gathered from this testing will also aid efforts to develop and refine applicable simulations for future use.

Calspan Learjet equipped with the EO cameras, AI-130 radar, and airspace deconfliction technologies that make up the SAA system test platform (photo courtesy of Calspan Flight Research)

The team plans to conduct two more rounds of MIAA flight activity, with the ultimate goals of demonstrating the system's capacity (1) to detect and track multiple aircraft on potentially conflicting paths with the test platform; and (2) to maneuver the craft safely, passing well clear of the conflicting aircraft and thus avoiding collision. The SAA team comprises engineers, pilots, technicians, and mechanics from AFRL; Northrop Grumman (prime contractor); Calspan Flight Research (flight test facilities); ICx™ Technologies (surrogate AI-130 airborne detection radar); Defense Research Associates (EO detection/tracking); Bihrle Applied Research (algorithm development and simulation); the Federal Aviation Administration's William J. Hughes Technical Center (flight test aircraft, precision positioning information, and technical advisors); and C2Projex (real-time situation awareness monitoring).

New Laser Tuning Technique Promises Better Remote Sensing of Chemical Threats

Highly magnified depiction of chirped grating enabling controllable tuning of laser emissions via laser physical positioning, a technology promising better remote sensing of chemical agents and other harmful substances

Whether on the battlefield or the city streets of home, early detection of chemical, biological, radiological, nuclear, and/or high-yield explosives (CBRNE) saves lives. AFRL, in collaboration with the University of New Mexico, devised and demonstrated a novel way of continuously changing, or "tuning," the wavelength of light emitted from a semiconductor laser. This new laser tuning technique could improve the capability to detect trace amounts of potentially hazardous chemicals from a distance. AFRL scientists expect this technology to migrate from early laboratory demonstrations to remote sensing applications, as well as other possible uses, in the next several years.

Remote sensing requires a laser with high brightness and a very narrow wavelength range of emission, as well as a means of controlling the wavelength during its transmission through suspect chemical clouds and/or pollution. By varying the wavelength, it becomes possible to trace the absorption signature of the laser light and look for the presence of a specific gaseous entity. Most simple gases, such as carbon dioxide, and complicated gases, including those used as components of lethal chemical weapons, have strong absorption signatures in the midinfrared wavelength range. Lasers meeting the criteria for remote sensing facilitate analysis of these signatures.

The AFRL/academic team devised an innovative application of the distributed feedback grating concept, wherein the teeth of the grating vary slightly, or "chirp," according to their position on the laser. The chirped distributed feedback grating enables continuous tuning of the laser's emission wavelength based on the laser's physical positioning. This new approach promises to replace the more complicated techniques currently in use for tuning laser wavelengths. Further, the novel tuning method paves the way for much-improved remote sensing schemes offering greater range and accuracy in detecting CBRNE threats.

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Engineers Test Actively Cooled CMC Panels for Rocket and Scramjet Engines

AFRL engineers, under an Integrated High-Payoff Rocket Propulsion Technology (IHPRPT) contract with Teledyne Scientific Company, completed environmental testing on actively cooled ceramic matrix composite (CMC) panels. The panels tested extremely well in both rocket rigs and scramjet [supersonic combustion ramjets] rigs, proving that CMC materials have the durability necessary for withstanding these extreme environments. CMCs boast two important attributes over current state-of-the-art engine materials—namely, they are lighter weight and have higher operating temperatures. Consequently, utilizing CMC components will lead not only to increased payloads and reduced operations cost, but to improved engine efficiencies and higher-velocity flight as well. The end result will ensure the availability of high-performance rocket engines and scramjets for future Air Force launch and hypersonic systems.

AFRL initiated this IHPRPT contract with Teledyne to develop CMCs as lightweight alternatives to the nickel-based alloys from which rocket engine and scramjet components are presently fabricated. The effort has achieved many innovations in CMC fabrication and has steadily advanced the technology readiness level of these materials for rocket and scramjet propulsion applications.

In one test, engineers evaluated actively cooled carbon-fiber-reinforced carbon silicon carbide (C/SiC) and silicon-carbide-fiber-reinforced C/SiC panels using Cell 22, a rocket rig used for assessing advanced rocket engine materials in an oxygen/hydrogen combustion environment. Researchers arranged the 3" x 10" test panels in the rig so that the high-temperature combustion gases (which reach 5800°F) impinged directly upon them. Thus, they subjected the panels to aerothermal conditions and heat flux equivalent to what would be experienced

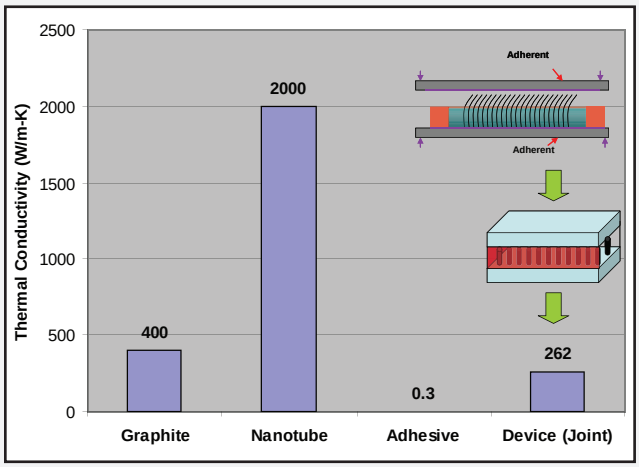
A cooled CMC panel undergoes a hot-fire test at the National Aeronautics and Space Administration's Glenn Research Center.

at the upper end of a typical boost engine nozzle (as with the space shuttle main engines). The test panels survived multiple firings of various durations, with a cumulative exposure of 40 min and individual cycles lasting up to 8 min. This oxygen/hydrogen rocket combustion exposure is the longest ever achieved for such actively cooled materials and equates to 5-10 launch cycles for a boost rocket engine (depending on flight profile).

The second test series took place in AFRL's scramjet rig. Engineers installed an actively cooled C/SiC panel in the combustor wall of the rig and subjected it to 20 engine runs lasting approximately 1 min each. Researchers observed that the test panel looked pristine after the testing.

Now that the durability of the materials and robustness of the cooled structures have been demonstrated in subscale, flat-panel configurations—and fabrication processes have been demonstrated for other shapes, such as bell nozzles—the next step towards advancing the technology will be to increase the size and complexity of test articles to better represent actual components.

Nanotubes Improve Thermal Conductivity in Adhesively Bonded Joints



Measured through-thickness thermal conductivity of the adherent (conductive graphite sheet), the adhesive, and the processed adhesive joint with vertically (through-thickness) aligned, multiwalled carbon nanotubes. The conductivity of the nanotube displays for comparison purposes.

AFRL research scientists are working with the University of Dayton Research Institute (UDRI) to explore innovative uses of nanotechnology for reducing aircraft life-cycle costs and improving aircraft systems reliability. The team recently demonstrated the conceptual use of multiwalled carbon nanotubes aligned to enhance thermal conductivity in adhesively bonded joints, an important step towards developing electric aircraft and reducing—or even eliminating—rotary power generation devices. The experiments used conductive graphite sheets and nanotubes aligned vertically along bonded joint thickness. The findings revealed that using carbon nanotubes in this manner resulted in thermal conductivity exceeding that of conventional counterparts by several orders of magnitude. By demonstrating a significant increase in the through-thickness thermal conductivity of adhesively bonded joints, this research has created new opportunities for advancing military and commercial aviation.

In nearly all cases, heat-generating devices aboard aircraft are attached to structural elements via adhesively bonded joints. Under current system design methods, these joints provide relatively poor thermal conductivity. Addressing this shortcoming will optimize the potential of expended heat to be leveraged rather than wasted. The approach of mixing carbon nanotubes or nanofibers in the adhesive material provides only a slight improvement. The solution, therefore, must include a substantial increase in the through-thickness thermal conductivity of the joints.

AFRL and UDRI researchers carefully examined the material configuration, opting to align the multiwalled carbon nanotubes vertically (along the joint thickness) in order to enhance through-thickness thermal conductivity. Initial numerical data indicated that thermal contact of the conductive phase with the adherent surfaces is essential to achieving the desirable level of through-thickness conductivity.

The team determined the thermal conductivity of the adhesive joint system by measuring thermal diffusivity via a laser flash (i.e., heat pulse) technique, which is capable of measuring the thermal diffusivity of solid materials over a temperature range of –180°C (centigrade) to 2000°C. The technique consists of first applying a brief pulse of heat (via the laser) to one face of the parallel-sided material sample. The next step is to monitor the rise in temperature that occurs on the opposite face as a function of time, obtaining measurements with an infrared detector.

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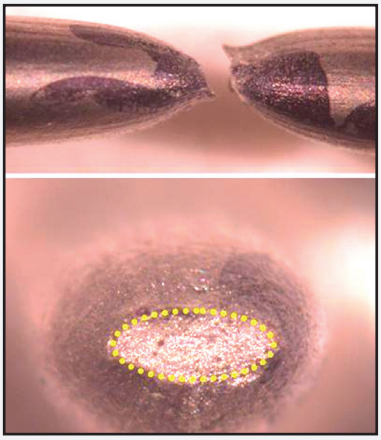
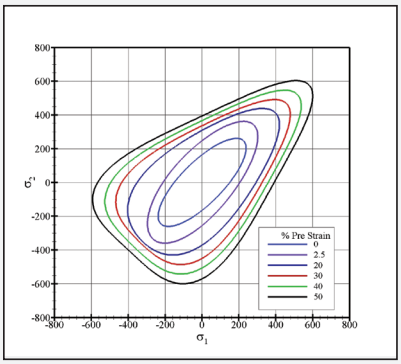
Engineers Develop Anisotropic Material Modeling

AFRL engineers developed and implemented new material models that accurately predict the behavior of highly anisotropic materials. The models are formulated for implementation across continuum-level finite element codes but can also accommodate the evolution of texture and deformation mechanisms occurring on a much smaller-length scale, such as that associated with crystallographic slip and mechanical twinning. These models can also account for the strength differential existing in some materials, wherein tension is much stronger than compression (or vice versa). The new models enable engineers to leverage the anisotropy resulting from mechanical processing, as well as the anisotropy inherent to hexagonal close-packed (hcp) materials such as zirconium and titanium. This modeling capability will lead to smart munitions that are tunable to a wider range of targets identified in real time.

Whereas current anisotropic models cannot accurately account for a strength differential between tension and compression, the new models can. Further, they accurately and efficiently model anisotropic materials exhibiting no strength differential. The two models that have been implemented and tested describe the orthotropic behavior of hcp materials. The theoretical yielding description is modifiable via linear transformation to an orthotropic description. The model parameters available from these transformations are quantifiable via conventional unit-level testing procedures, such as uniaxial stress measurement, for various orientations of the material. Rate effects are easily incorporated using data gathered from Hopkinson bar-type tests. In order to account for the anisotropic hardening observed in many materials, researchers developed an interpolative hardening procedure that is easily implemented. The models are first parameterized for various levels of plastic strain, and the procedure subsequently interpolates for effective strain levels occurring between any two levels.



Results from tensile Hopkinson bar experiment of an initially circular cross section. The anisotropic properties of the hcp material cause the final cross section to be highly elliptical (photo courtesy of Philip Flater AFRL/RWMW).



Evolution of yield surface versus strain level for hcp material showing clear strength differential

When experimental data is not readily available, data from polycrystalline simulations can provide data for parameterization of the models. To this effect, researchers from AFRL and Los Alamos National Laboratory collaborated to use VPSC (Visco Plastic Self-Consistent Code) to provide data (supplementing experimental data) in order to parameterize the models, which they then validated both against beam bend tests for quasi-static rates and against cylinder impact tests for loading higher rates.

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Tests of Decision-Making Fuze Technology a Success

AFRL and Alliant Techsystems members of the RIVAL fuze team

The drive towards faster, more accurate and capable weapons for defeating hardened and deeply buried targets has created the need for intelligent fuzes capable of active decision making under high-impact conditions. The Robust Intelligent Void and Layer (RIVAL) fuze provides an accurate, "smart" fuzing solution for hard-target defeat. AFRL teamed with Alliant Techsystems to conduct penetration tests demonstrating the RIVAL fuze's capacity to detect, defeat, and survive layered hard targets.

The researchers performed cannon and sled testing of the RIVAL fuze. They subjected the fuzes to a severe high-g shock environment, using AFRL gun testing capabilities to fire subscale projectiles into various concrete targets. The team then tested the RIVAL fuze in a 2,000 lb class penetrator, installed on a rocket sled and subsequently fired into a complex, multilayered target. The twofold purpose of these tests was to collect accelerometer data and evaluate fuze survivability and functionality (specifically, inert detonator firing) under the extremely high impulse loads commonly produced during penetration events. The RIVAL fuze includes the first domestically designed and built intelligent module that not only senses voids, layers, and distance traveled, but contains its own data recorder for capturing both these decisions and the penetration event itself. The fuze configuration includes three different accelerometers, each mounted at a different location and using a different mounting technique. For the tests, a Media Discrimination Module monitored the first accelerometer, while a Versatile Fuze Recorder (mounted externally, in the booster cup) monitored the second. Monitoring of the third accelerometer occurred via an Electronic Control Module, the mounting scheme of which resembles that of earlier AFRL-designed fuze products.

During testing, all RIVAL fuzes successfully fired their respective inert detonator and recorded deceleration data needed for active fuze decision making. This marks the first time that three different accelerometers, each monitored by an independent recorder, were able to successfully collect penetration data from three different locations within the same fuze. This valuable accelerometer data also provides critically important environmental information, which will aid efforts to design and evaluate future fuze devices. Remarkably, the several fuzes used throughout the multiple tests all survived penetration and remained fully or partially functional afterward. These test results represent another milestone in AFRL's ongoing progress towards optimizing the effectiveness of active decision-making fuze technology.

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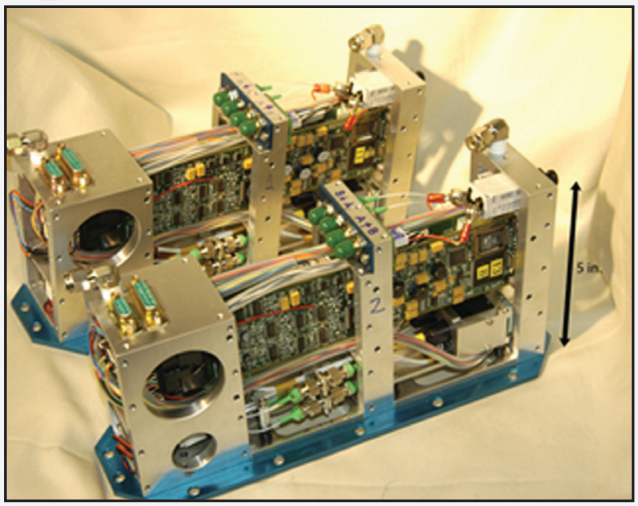
Pulsed-Detonation Engine Powers Manned Aircraft

Aviation's first-ever flight test of a manned aircraft powered by a pulsed-detonation engine (PDE) was a success. An AFRL-designed PDE that produced greater than 200 lbs of thrust powered the Long EZ test aircraft, which achieved a speed of 120+ mph and an altitude of 60-100 ft. AFRL propulsion researchers worked alongside experts from industry partner Innovative Scientific Solutions, Inc., to develop and manufacture the engine in-house. The success of this effort is attributable to the active involvement and collaboration of multiple AFRL technical disciplines in completing the range of required activities, including the research and development associated with the PDE and propulsion package; the structural support, aero, and acoustical components; the pilot exposure limits and acoustic protection; and the structural materials. Scaled Composites, Inc., provided vehicle integration and flight test support.

Long EZ aircraft powered by PDE

Miniaturized Laser-Based Measurement Capability Aids Scramjet Engine Performance Analysis

Air Force SBIR/STTR



TDLAS measurement platform

AFRL scientists are working with industry partner Southwest Sciences, Inc., to prepare for the first flight test of a diode-laser-based measurement platform. The test is part of the Hypersonic International Flight Research and Experimentation (HIFiRE) program and is receiving support from the Air Force (AF) International Cooperative Research and Development, AF Small Business Innovation Research, and Department of Defense Test and Evaluation/ Science and Technology (high-speed/hypersonic test focus area) programs. The team has adapted and miniaturized laser-based telecommunications technologies and custom digital signal processing electronics to develop a unique measurement platform employing tunable diode laser absorption spectroscopy (TDLAS).

The TDLAS platform provides a novel approach to measuring gas species and velocity within an engine flowpath in flight. The method employs a highly sensitive measurement technique known as wavelength modulation spectroscopy, along with kilohertz frequency sampling rates, in order to gain maximum information from flight experiments. This effort marks the first time that the technology has undergone miniaturization for use at scales suitable for sounding rocket flight experiments, wherein the instrument mass and power requirements are ~2 kg and ~2 W, respectively.

HIFiRE represents a 7-year bilateral agreement with Australia to conduct research in the exploration and development of fundamental hypersonic aerospace technologies. TDLAS experiments are scheduled for three of the HIFiRE sounding rocket flights. These activities will focus on developing new flight-qualified, nonintrusive techniques capable of measuring core flow properties in real time in order to characterize critical vehicle/engine parameters, such as air mass capture, stability limits, and combustion progress.

Scientists have qualified the diode-laser flight hardware to operate over unprecedented temperature and vibration conditions. The team expects that the TDLAS measurement platform will achieve Technology Readiness Level 6 status (i.e., system/subsystem model or prototype demonstration in relevant environment, ground or space) upon completion of HIFiRE's culminating exercise, a Mach 8 scramjet [supersonic combustion ramjet] propulsion flight.

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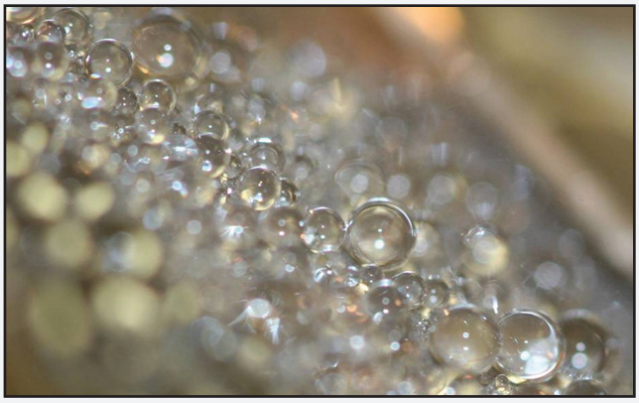
Testing of Advanced Lab-Developed Monopropellant a Success

Pursuant to Phase II spacecraft chemical propulsion objectives of the Integrated High-Payoff Rocket Propulsion Technology program, AFRL researchers synthesized an advanced monopropellant using hydroxylammonium nitrate, an energetic salt, as an ingredient. Formulation of this product, AF-M315E, occurred at Edwards Research Site (Edwards Air Force Base, California) over a 10-year period. In recent product assessment activity funded by the Missile Defense Agency, the approximately 360 lbs of AF-M315E used for external fire testing exhibited little reaction, other than benign burning triggered by its placement into an already intensely burning fire. This successful result bodes well for favorable decisions regarding both AF-M315E's hazard classification and its potential use aboard ship-based platforms. Additional tests performed throughout the next year will facilitate preparation of the final hazard classification submittal package.

AF-M315E propellant fast cook-off test

Lab-Funded Transparent Coating Repels Water



Water beads up into droplets that roll or bounce off a transparent coating.

A team of AFRL-sponsored researchers developed a transparent coating that causes water to bead up into drops and roll or bounce off the surface. This technology will help protect and sustain Air Force systems by preventing corrosion and reducing ice formation on optical elements and aircraft.

The researchers are employing this emergent technology not only to repel water, but also to design a surface capable of drawing water from humid air. The new surface combines extremely water-repellent and water-absorbent areas to create the desired effect. Modeled after the Namib Desert beetle's unique biological capacity to extract moisture from its arid environment, this bioinspired technology could provide troops an energy-free method for collecting water in areas where resources are scarce.

Producing and applying a coating with superhydrophobic—or super-water-repellent—properties required that the researchers control coating roughness and surface chemistry on a small scale. The team, comprising researchers from the Brinker Nanostructures Research Group (University of New Mexico) and Sandia National Laboratories who were already known for their break throughs in aerogel thin-film processing, leveraged its members' earlier research in devising a simple way to deposit the coating on every contour of a given surface by spraying, spinning, and/or dipping. The team's simple modification of a chemical precursor reversed the shrinkage that typically occurs as a coating dries. The chemical alteration yields a substance that springs back, creating a nanoporous surface with superb water-repellant properties.

The most recent advancement in this research is the ability to selectively pattern the coating and spatially control the wetting behavior for a desired application. The team's recent work has opened the door to new applications that exploit the way in which the coated surface interacts with liquid droplets. When water droplets roll along the coated surface, they pick up debris as they go. This property might enable the collection, concentration, and identification of aerosol-borne particles, such as anthrax. In addition, the research results will likely transition to commercial use, aiding applications such as the protection of electronics and other valuables from water damage.

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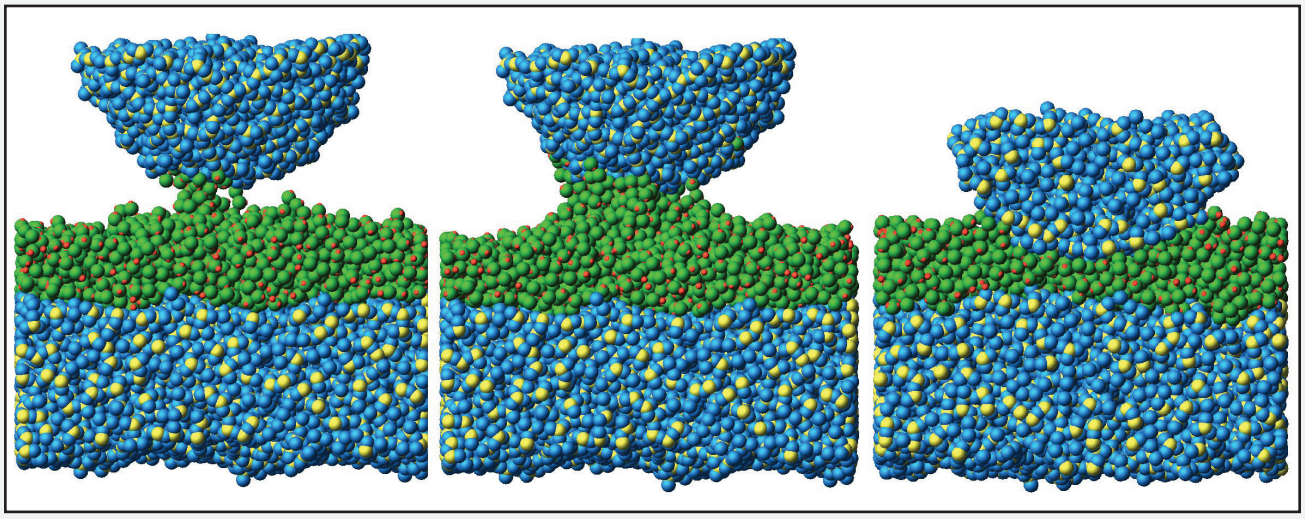
Computer Simulation Shows Unusual Properties of Water on Nanoscale



Computer simulation showing water's unusual properties on the nanometer scale

AFRL funding helped a theoretical physicist become the first in his field to conduct a computer simulation revealing water's unusual properties on the nanometer scale. A team led by Dr. Uzi Landman, director of the Center for Computational Materials Science at the Georgia Institute of Technology, discovered the formation of liquidlike layers for water films 1 nanometer thick. In a horizontal position, the water can flow, whereas in a vertical position, it acts like a solid.

Dr. Landman's work is motivated by his great interest in understanding the properties of highly confined water in the context of miniaturized machinery. His research program at Georgia Tech covers a broad spectrum of topics, ranging from atomic-scale phenomena of fluid nanojets to electron quantum dots and trapped cold atoms.

Finding ways to manipulate and control the properties of fluids on atomic and molecular scales and under extreme conditions has important implications to the design and development of future Air Force materials and devices. The novel behavior of water emerges when materials are in nanoscale dimensions, and their behaviors cannot be determined based on an existing knowledge of larger devices. Future technological and engineering applications of nanoscale materials will therefore require new, nanoscale-based design principles.

Discovery

Page

Opportune Landing Site Testing Proves Successful

The AFRL-managed Opportune Landing Site (OLS) program recently conducted two successful landing site soil tests. Boeing and the US Army's Cold Regions Research and Engineering Laboratory jointly developed the OLS software, which uses satellite imagery, digital terrain elevation data, and Air Force Weather Agency data to help find suitable landing sites for aircraft. The software analyzes terrain characteristics such as width, length, and flatness to determine whether the location is free of vegetation, standing water, and obstructions.

In the first round of tests, conducted at Vandenberg Air Force Base (AFB), California, Air Force Civil Engineering Service Agency researchers collected soil samples of terrain chosen by the OLS software. The soil underwent analysis and comparison to OLS system data. Test results revealed that the OLS software model had accurately predicted both soil type (to a depth of 30 in.) and soil hardness (strength). Additional testing, conducted at Holloman AFB, New Mexico, partially reinforced these preliminary findings: while actual soil type did not match predictions, the OLS software once again proved itself a reliable predictor of soil strength.

Pilots could use OLS software in conjunction with other analysis tools to assist their landings in natural terrain. The software therefore has the potential to increase the capabilities of mission-critical vehicles such as transport aircraft. It could also broaden the range of possible landing options for military aircraft, saving time and money. The OLS program is funded under the US Transportation Command's Technology Transformation Initiative and directed by Air Mobility Command. SynGenics and General Dynamics Advanced Information Systems provide systems engineering support for the program.

Researchers from the Air Force Civil Engineering Service Agency conduct soil testing.

For more information contact
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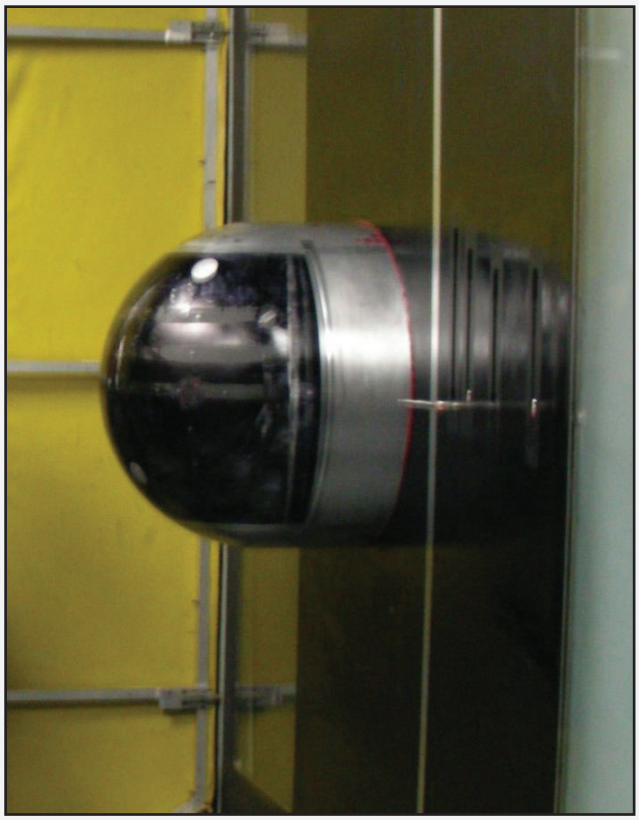
Directed Energy Beam Improvement System Tested



DEBI-BATL turret model in AFRL's Subsonic Aerodynamic Research Laboratory wind tunnel

AFRL completed active flow control testing of DEBI-BATL, the Directed Energy Beam Improvement [system using] Binary Control for the Advanced Tactical Laser. The tests involved a turret model with active flow control devices installed. DEBI-BATL program efforts seek to reduce the amount of aero-optic interference surrounding an aircraft turret. "Aero-optic interference" refers to the distortion that a beam (such as a laser beam) experiences as a result of turbulent airflow around an air vehicle in flight. This interference can adversely affect communications, targeting, and other aircraft systems. Even a small distortion at the beam's source can instigate significant optical distortion over a long distance.

To help combat aero-optic interference, AFRL researchers tested the impact of active flow control devices positioned strategically on the surface of a turret model. These devices are small pulsating jets that alter the flow of air around the vehicle, suppressing turbulence. In this most recent test series, researchers sought to determine the optimum configuration of flow control devices for producing the maximum reduction in aero-optic interference. After placing the turret model on the sidewall of AFRL's Subsonic Aerodynamic Research Laboratory wind tunnel, they measured airflow around the turret using several methods (e.g., particle image velocimetry, hot wiring, and static and sound pressure sensing). These methods facilitate accurate determination of airflow patterns around test objects. The team tested the turret at various angles, at speeds from Mach 0.1 to Mach 0.5.

Upon successful completion of this test series, the researchers recorded their data in order to assist the AFRL and Boeing team prepare for additional testing. The upcoming test effort will measure the effectiveness of active flow control devices in controlling aero-optic distortion for high-energy laser (HEL) applications. HELs are candidates for potential integration into aircraft intended as tactical weapons, wherein minimizing aero-optic beam distortions in order to maximize weapon system effectiveness is essential.

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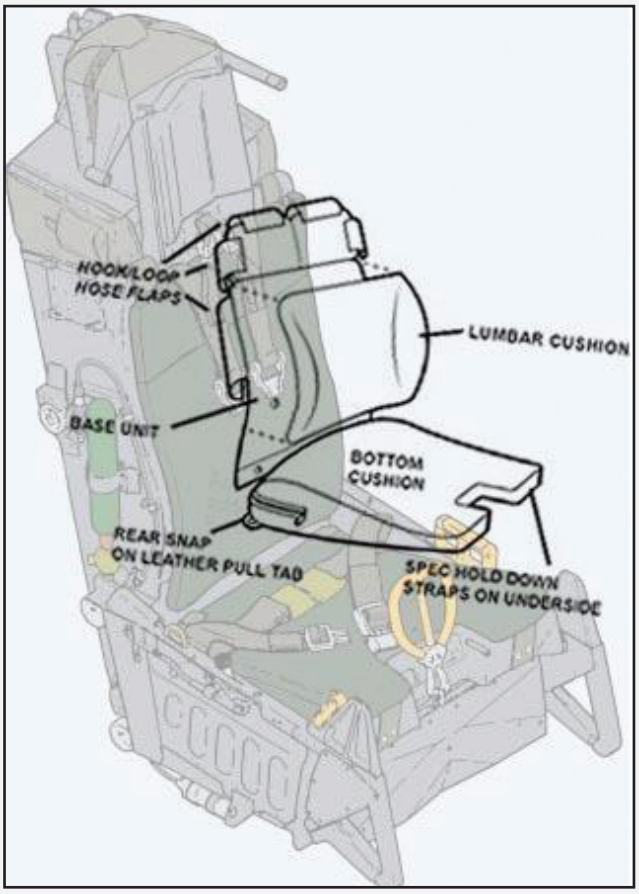
Engineers Conduct Pilot Feedback Study

AFRL engineers conducted a feedback study aimed at improving flight comfort levels for pilots flying ejection seat aircraft. The goal of the effort is to determine whether advanced seat cushion options can effectively reduce discomfort and improve mission effectiveness for pilots who conduct long flights. The team is investigating several prototypes, one of which is an air bladder seat cushion. To collect feedback regarding the seat cushions, the engineers used AFRL's Infinity Cube Simulators, which enabled the pilots to fly representative missions seated in a large-field-of-view cockpit mirroring that of an actual aircraft.

During the simulations, 11 different pilots carried out 4 separate instrument-system landings for each seat cushion concept. In this manner, the pilots tested and evaluated every seat cushion for each simulated mission. The engineers collected flight performance data, while the pilots completed questionnaires assessing each seat cushion prototype after each mission flown. Both the pilot feedback and the measurable data acquired from these tests will aid determinations concerning which seat cushion provides pilots the greatest benefit for long flights and also meets ejection seat aircraft requirements.



AFRL seat cushion concept

New System Enables Friend-Versus-Foe Identification

Member of the 455th Expeditionary Mission Support Group shown wearing TRON I

Military vehicle marked with TRON I (glowing strip in the center) and TRON III, as viewed through night vision goggles

AFRL developed a technology that helps warfighters distinguish friendly forces from adversaries during combat. The lab teamed with Lumitex, Inc., to create and field the Target Recognition Operator Notification system, which has the potential to save lives and increase combat effectiveness. Dubbed "TRON," the system uses fiber-optic panels and a light source to provide a light-emitting surface that permits more accurate identification of friend versus foe in the field.

AFRL partnered with Lumitex to further develop methods established by the Army. TRON consists of Lumitex's patented thin and flexible fiber-optic woven cloth, cut to military specifications. Individual sheets of the tailored cloth are laminated into layers that are then formed into lighting devices of various shapes and sizes. The woven nature of the cloth causes light to be emitted in a uniform, controlled way. Scientists expect the technology to be inexpensive and rapidly fieldable. TRON has a long battery life, running 200 hrs on two AA batteries; it also weighs less than 3 oz. Personnel can wear it under clothing, on outer tactical vests, on an arm, or mounted to a helmet. The team produced 108 prototypes in months.

TRON III, a larger system subsequently devised for identifying friendly force positions during close air support (CAS) operations, uses the same fiber-optic cloth as TRON but is six times brighter. TRON III's bright coloring improves daytime recognition. In addition, it hooks into a vehicle's power supply, eliminating the need for an external power source. This prototype's development occurred as a joint effort between AFRL scientists, who decided on the specifications, and Lumitex scientists, who built the system. The team fielded TRON III for testing just 3 months after the need for the system was established.

TRON I and III are currently aiding warfighters in deployed locations. Both systems were part of Red Flag, a joint air operation exercise held at Nellis Air Force Base, Nevada. In real-world conditions, TRON I has facilitated successful marking and cordoning of an unused improvised explosive device, which a bomb disposal team quickly identified and destroyed. TRON I has also supported over 40 CAS missions. TRON III, meanwhile, has played a role in at least two successful CAS missions.

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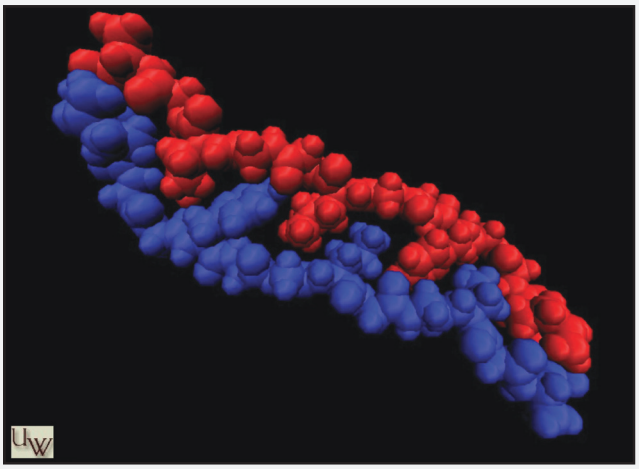
Researchers Use Artificial Spider Silk to Create Bulletproof Vests and Parachutes

AFRL is supporting a team of University of Wyoming researchers focused on investigating the use of spider silk proteins for creating biomaterials with military utility. The team is producing new proteins that can be spun into strong, lightweight, extremely elastic silk that can, in turn, be used to construct lightweight bulletproof vests for military personnel. Other uses for these manufactured fibers include the construction of much stronger parachutes (enabling larger payload delivery), as well as the creation of artificial ligaments.

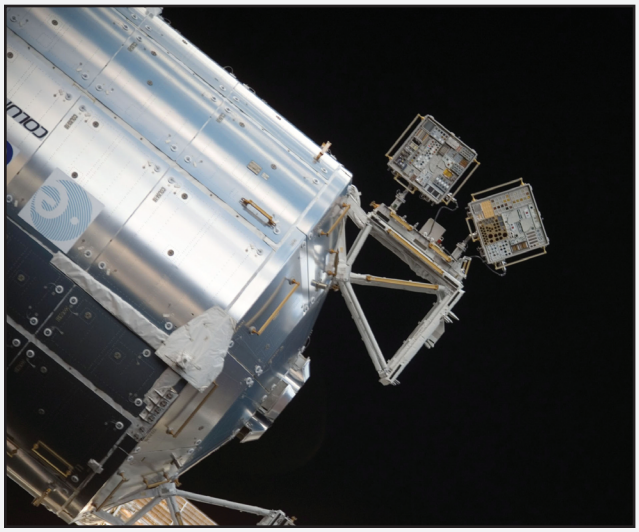
Producing useful quantities of natural spider silk has previously proven unrealistic because of challenges inherent to managing large numbers of spiders—creatures that are not only small but typically cannibalistic as well. Consequently, researchers are turning to artificial spider silk, which is both stronger than the polymer known commercially as Kevlar and more flexible than nylon.

The AFRL-supported researchers are using a method wherein they first produce spider silk genes and then place them in a bacteria-laden environment, an interaction that yields chemically identical spider silk proteins for use in experiments. In addition to spinning these fabricated proteins into fibers and testing them for better properties, the research team has also produced genetically modified goats that produce milk containing the spider silk proteins. Overall, the team has produced 15 new spider silks and continues work towards improving both the properties of these silks and the process of spinning the fibers. Estimates indicate that while spider silk body armor may cost twice as much as Kevlar body armor, the product's minimal weight, remarkable strength and elasticity, and potential adaptability for other needs are characteristics that ultimately enhance its marketability.



The interaction of two spider silk protein molecules resembles a zipper's workings, with the zipper's teeth visible in one molecule's slots. Occurring on hundreds of thousands of proteins, such interactions help form the spider silk fiber and contribute to its extraordinary strength (image courtesy of Dr. Randy Lewis).

Researchers Explore Materials Degradation in Space



Two small passive-experiment containers filled with new materials and mounted to the ISS for AFRL's MISSE-6 effort (NASA-provided photo)

When *Space Shuttle Endeavor* launched in March 2008, it carried aboard more than 500 new materials for testing as part of the sixth Materials International Space Station Experiment, or MISSE-6. AFRL initiated MISSE-6 to gain a theoretical understanding of the mechanisms involved in materials degradation as it occurs in space. MISSE-6 results will help scientists better understand the durability of various materials in the harsh space environment. In turn, recognizing which materials are truly suitable for space use will have important implications to the design of future spacecraft.

In low earth orbit—the zone beginning roughly 50 mi above the earth's surface and extending to a distant 1,240 mi—materials erode more quickly than in other environments. This accelerated degradation stems from the material's exposure to ultraviolet rays and atomic oxygen, an elemental form of oxygen not found in earth's atmosphere. MISSE-6 consists of two passive-experiment containers, resembling suitcases, attached to the outside of the International Space Station (ISS). Each container houses small samples of the hundreds of materials being tested for space exposure effects.

Some of the materials selected for MISSE-6 include an extremely hard, ceramic-like material (developed at the University of North Dakota); silica-encapsulated enzymes and cells (prepared by UES, Inc.); and spider silk thread (from Oxford University). AFRL and industry partner Boeing assembled and installed the material samples before sending the MISSE-6 containers to the National Aeronautics and Space Administration's (NASA) Langley Research Center for testing. Boeing is the prime contractor used by NASA to design, develop, integrate, test, and deliver US-built components of the ISS.

An astronaut carried both MISSE-6 containers outside the shuttle and mounted them at designated locations on the ISS. Following 1 year of exposure, another team of astronauts will retrieve the containers and return the material samples to earth. Researchers will then evaluate the materials based on their respective reactions to atomic oxygen erosion, direct sunlight, radiation, and extremes of heat and cold. This assessment will aid the determination of which materials can withstand the harsh space environment.

MISSE-6 is the first of the MISSE efforts to test biomaterials. In addition to its passive experiments, this sixth-running mission also includes several active experiments, such as shutters, biases placed on samples, and real-time data recording. Further, MISSE-6 is the first experiment of its kind to employ space station power, a benefit enabling astronauts to respond more quickly should any experiment encounter problems. The groundwork required for connecting to space station power has, in turn, paved the way for a MISSE-7 data link capability.

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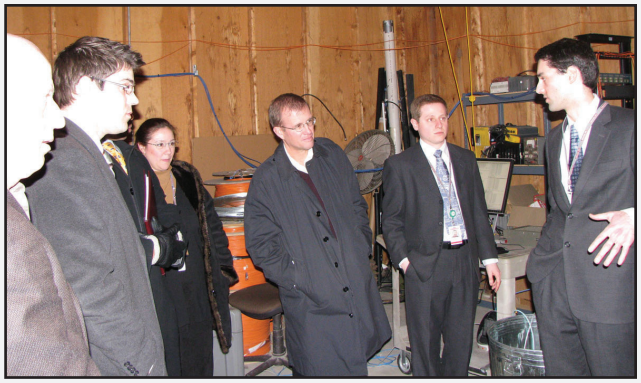
AFRL-Funded Research Leads to Better Wireless Communications

The research contributions of Dr. Rachel Learned, an AFRL-funded researcher employed by BAE Systems, have paved the way to clearer radio reception for military personnel deployed in locations prone to signal interference. Through her work in multiuser detection (MUD), which examines the reception of radio signals that interfere with one another, Dr. Learned was able to develop a scheme for organizing both the interfering transmissions and the corresponding receivers' processing algorithms. The novel organizational architecture facilitates the use of small, lightweight, real-time receivers to pull apart interfering signals and thus clear the air for improved wireless communications.

Dr. Learned continues to work towards advancing wireless communications, focusing particularly on scenarios wherein the number of interfering radio signals is extremely high. In 1998, she established a research and development (R&D) group at BAE Systems and began to champion the adaptation and advancement of MUD for military applications. Largely the result of this group's R&D efforts, there now exists radio technology enabling concurrent (multiple-user), shared-frequency transmission.

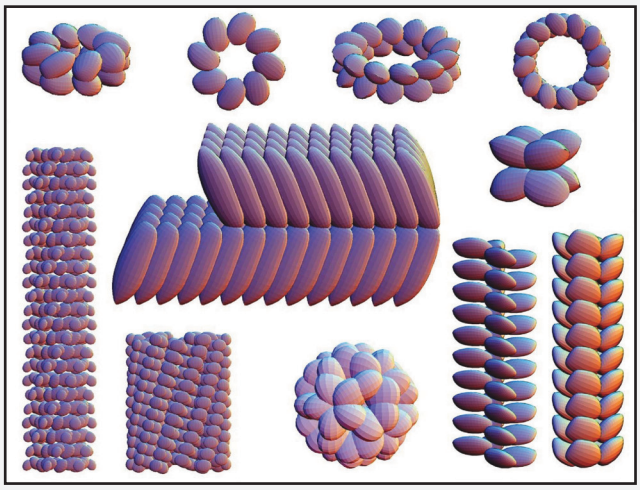
In Iraq, MUD technology could prove very helpful in areas where interfering electronic transmissions substantially reduce the amount of critical military communications that can be transmitted. MUD technology accommodates more traffic on various networking systems, affording an advantage to military personnel in critical need of high-throughput air-to-air, air-to-ground, and person-to-person communications.



Pictured left to right are BAE Systems/DARPA MUD Radio Development team members Mr. Joshua Niedzwiecki (BAE), Dr. Rachel Learned (BAE), Dr. Brian Pierce (DARPA), and John Tranquilli and Joseph Farkas (BAE).

BAE Systems is also striving to advance MUD technology by demonstrating its capacity to operate without infrastructure and power control. In addition, the Defense Advanced Research Projects Agency (DARPA) has furthered the technology's evolution by developing new MUD algorithms for the DARPA Interference Multiple Access program, an effort instated to build upon original MUD-based capabilities. The enhanced technology resulting from the DARPA effort will enable warfighters to dispense critical intelligence during battle by exploiting multichannel interference to achieve high-capacity, low-latency, spread-spectrum communications.

"GameChanger" Research to Improve Antennas for Micro Air Vehicles



Examples of objective structures

As part of his project called "GameChanger," Dr. Richard James (an AFRL-funded professor from the University of Minnesota) is using the concept of objective structures to create new antennas for micro air vehicles (MAV) used for military purposes. MAVs are a type of remotely controlled unmanned air vehicle. The challenge of designing a suitable antenna for these vehicles is related to their small size, which prohibits standard solutions.

Dr. James and his students regularly develop theories regarding the behavior of materials; they then take these theoretical predictions into the lab to aid the creation of useful new materials. In exploring revolutionary new materials—for efficient MAV antennas, in this case—the GameChanger effort centers on Dr. James' discovery of a systematic approach to nanotechnology. The approach hinges on the use of objective structures, which are structures composed of atoms with identical molecules existing in the same atomic environment.

The methodology, which leverages a number of innovative and powerful mathematical tools, produces materials resembling carbon nanotubes. These novel materials consist of the natural structures—and thereby exhibit the associated natural behaviors—needed for seeking special physical properties, such as ferromagnetism and ferroelectricity. Ideal for antenna applications, this inherent "seeking" characteristic is a consequence of the material's objective-structures-based composition. That is, the material makeup is such that if one atom exhibits unpaired spins (i.e., is magnetic), all of the atoms will display this same behavior (i.e., magnetism).

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Solar Sails Developed for Space Missions

AFRL engineers developed a micro solar sail concept with unique deployment features that promote its usefulness for many new Department of Defense space missions. The concept's robust deployment scheme enables simultaneous and deterministic deployment of both masts and main sail. Rather than relying on mechanical joints typical of a planar space structure, this architecture utilizes elastic deformation to enforce deployment kinematics. The four column-loaded, cruciform-configured, self-deploying, triangular, rollable and collapsible masts support a perimeter of outer spar members that are continuously tensioned throughout deployment. This scheme enables the spars and membrane film to unfold in a deterministic manner, giving the system exceptional dynamic stiffness levels during deployment.

Since the masts are self-deploying, the central actuator's only function is to control deployment rate. AFRL engineers constructed a 7.5 m^2, full-scale prototype of the micro solar sail concept to demonstrate feasibility of the unique structural architecture. The prototype includes a central hub and deployment mechanism, support masts, main sail film, radial cords, and spars. This prototype completed dozens of nearly flawless deployment cycles that verified basic system functionality and demonstrated critical function and robustness of the carbon-fiber-reinforced plastic spar members. To validate the highly nonlinear finite element techniques used to analyze structural performance, the engineers took a series of photogrammetric measurements of the perimeter spars at several instances during deployment and compared this data to structural analysis predictions. Further development efforts are under way to advance the concept's readiness level.

Solar sail

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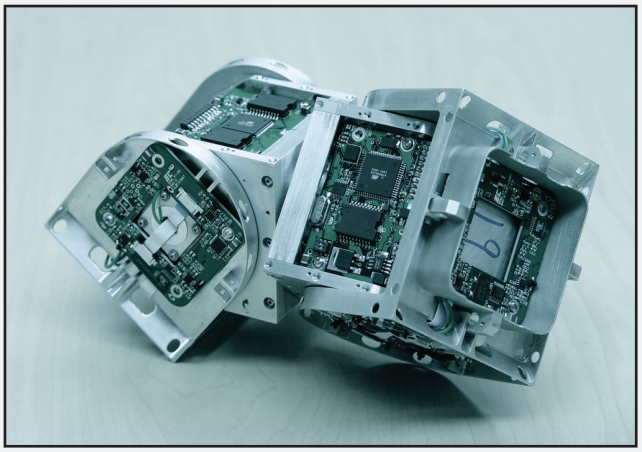
SuperBot Research Supports Air Force Information Dominance



Single-module reconfigurable robot capable of autonomously changing its physical shape, size, or formation (photo courtesy of Dr. Wei-Min Shen)

AFRL is funding research aimed both at improving SuperBot prediction capabilities and at creating algorithms enabling the robot to detect surprise. SuperBot is a modular, multifunctional, and reconfigurable robot. Conceptually, it is a set of individual robots that work together to solve problems. Developing any technology that expands a robot's capacity to "learn" from its surroundings is a difficult undertaking, one demanding rigid investigation and meticulous mathematical calculation. The AFRL-sponsored effort to realize "surprise-based learning" is no exception.

This research directly supports the Air Force vision of information dominance and "anywhere, anytime" operational readiness by facilitating the warfighter's ready assimilation of new information in a distributed fashion. Future robots will be capable of changing their own configurations in order to adapt in response to new and unexpected situations, such as those arising from space or ocean exploration efforts, disasters, or any similarly hazardous operational environment. These futuristic 'bots will possess self-healing properties as well, enhancing their resiliency to damage sustained during such missions.

Leading the SuperBot research team is Dr. Wei-Min Shen, director of the University of Southern California (USC) Polymorphic Robotics Laboratory, associate director of the USC Center for Robotics and Embedded Systems, and research associate professor in USC's Computer Science Department.

The National Aeronautics and Space Administration is interested in SuperBots and is incorporating the results of this AFRL program into a larger-scale SuperBot project that it is funding.

For more information contact
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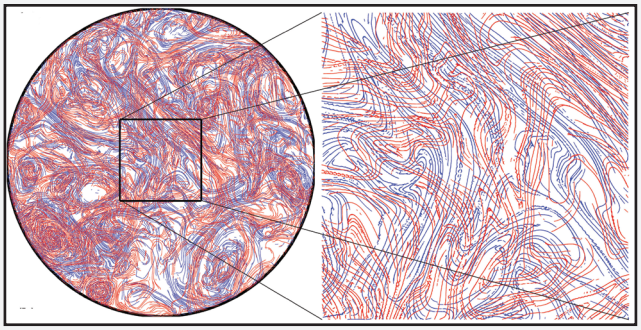
Air Turbulence Research Could Enable Safer Flight Operations

AFRL is funding Massachusetts Institute of Technology (MIT) scientists who are researching ways to identify and predict turbulence through the detection of underlying air patterns. Dr. George Haller, professor of mechanical engineering, and MIT graduate student Manikandan Mathur lead a research team exploring the impact of turbulence on engines, airframes, and, consequently, air travelers. The two have made a discovery they refer to as the "Lagrangian skeleton of turbulence," since the work of 19th century mathematician Joseph-Louis Lagrange inspired the team's particle-based approach.

The air pattern structure underlying turbulence is a complicated, ever-changing configuration that affects the motion of nearby particles (e.g., pollutants, stratospheric ice crystals). Monitoring the backscattering of onboard lasers enables detection of this particle movement, which serves as a reliable predictor of ensuing turbulence. The MIT scientists used nonlinear, dynamical systems theory to translate the recorded data necessary for uncovering these effects.

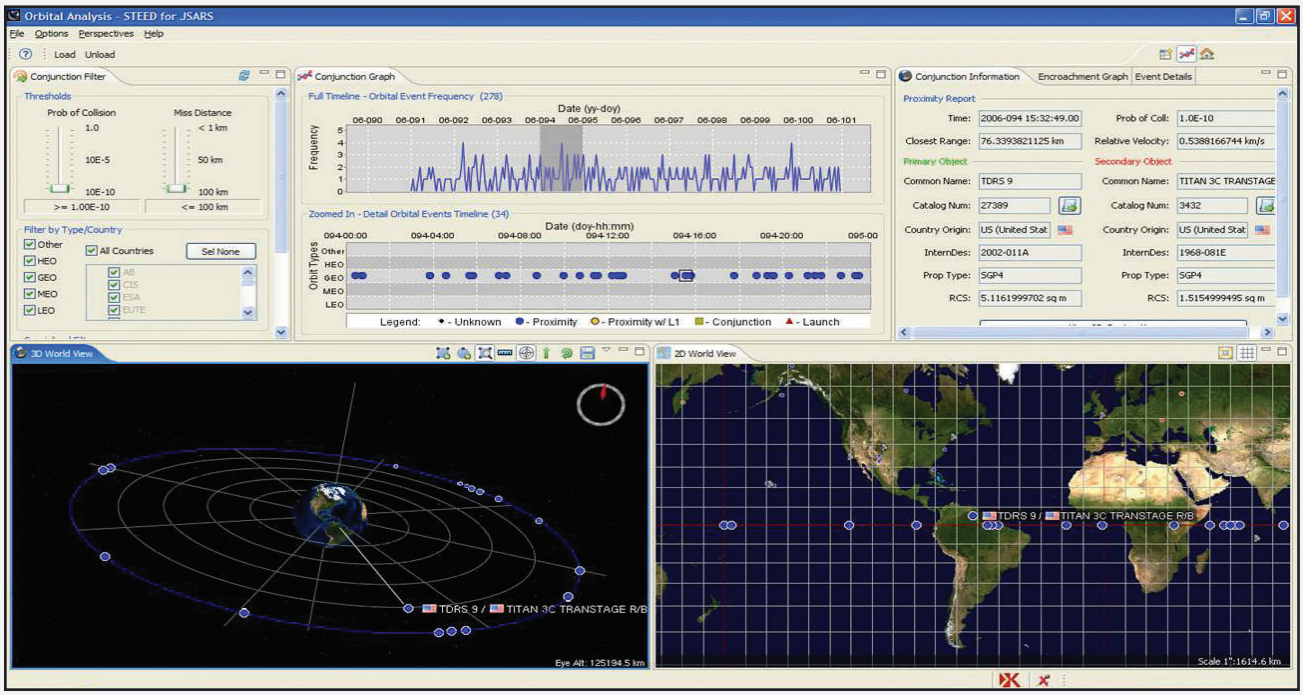
Researchers believe the detection of these underlying structures will make it possible to forecast clear-air turbulence, a capability of benefit to manned and unmanned military aircraft alike. The work is equally important for the safety of high-altitude Air Force operations, as well as the stable pointing of onboard laser weapons. Ultimately, this Lagrangian skeleton approach could also be used to locate the source of dispersed chemical or radioactive pollution, thus improving homeland security.



Depiction of Lagrangian skeleton of turbulence approach in a flow experiment (image courtesy of MIT Professor George Haller)

The team is currently working to reduce the time it takes to produce detailed images of detected structures. The researchers are also developing laser-based scanning techniques that yield more complete wind data.

Prototype Decision Support System Improves Situational Awareness



Orbital analysis screen shot from AFRL's JSARS

Prompted by an Air Force request for improved situational awareness, AFRL initiated development of the Joint Situational Awareness & Response System (JSARS). The specific aim of this Core Process 3 effort was to provide the Joint Space Operations Center (JSpOC) with a prototype decision support system enabling improved situational awareness. In addition to satisfying its intended purpose as an early prototype system for JSpOC use, the resulting JSARS product also addresses technical difficulties related to the Rapid Attack Identification Detection and Reporting System. The technology thrusts associated with the JSARS effort include threat detection, tracking, relationships, and situation assessment.

A collaboration of Small Business Innovation Research (SBIR) contractors developed the JSARS decision support product, a prototype system that incorporates AFRL technologies spanning a broad range of science and engineering disciplines. The development team consisted of members from CleverSet, Data Fusion & Neural Networks, Charles River Analytics, The Design Knowledge Company, Intelligent Software Solutions, and Metatech Corporation. The Aerospace Corporation and APL Limited provided support services for the effort. The variety of advanced technologies employed for this SBIR effort resulted in the system's demonstrated capacity for multisource data fusion via orbital catalog, space weather, intelligence, and telemetry data. The JSARS technology has since undergone successful transition to the Space and Missile Systems Center. AFRL has plans for follow-on work geared towards enhancing the system's capabilities.

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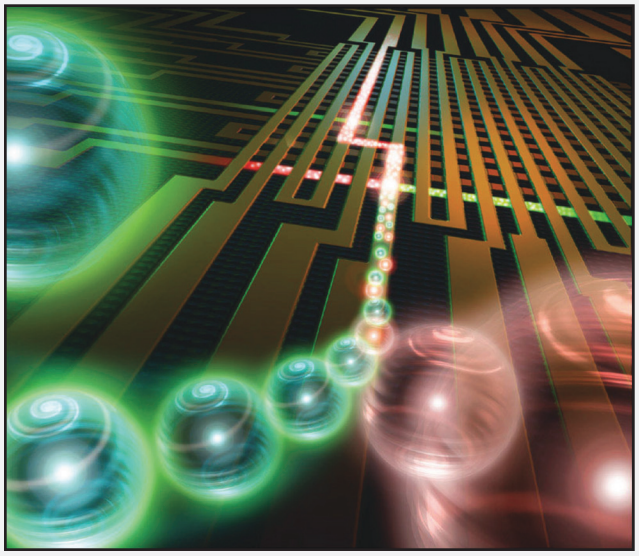
Scientists Use Spintronics to Power Quantum Computers

AFRL-funded scientists used a single-photon technique to observe the evolution of individual electron spins in semiconductor nanostructures. Dr. David Awschalom—a professor of physics, electrical, and computer engineering at the University of California, Santa Barbara—is coordinating the research. He and his team are exploring the benefits of spintronics-based electronic devices for powering quantum computers containing diamond components.

Spintronics refers to the spin of electrons that causes a behavior resembling that of tiny magnets. The scientists' work has already contributed to the new field of semiconductor spintronics. By subsequently using spintronics in quantum computing, they will be able to control electrons and create higher-speed technologies not possible in the present-day realm of electronic equipment.

The researchers found that not only is diamond an electrical insulator but, when combined with other elements, it becomes a semiconductor with formidable properties for computers and solid-state microwave electronics. The newfound ability to grow nanometer- to micron-sized synthetic diamond is already beginning to enhance the field of semiconductor spintronics and quantum information processing.

The research team is currently learning how to engineer new quantum spin circuits that will require precision placement of atoms within diamond at predetermined locations. The team is also investigating ways to "wire" the spins together and, in doing so, exploit the resulting quantum mechanical properties for novel information processing and secure communication.



Graphic illustration of semiconductor spintronics

The greatest impact of a future quantum computer lies in the belief that the technology will be uniquely capable of simulating other quantum systems, something current computers are unable to do. Quantum simulations will be necessary for understanding and predicting the behavior of matter at the nanometer scale and could therefore bring huge advances in physics, chemistry, materials science, and biology.

Air Force Striving to Enhance Communications Networks

The European Office of Aerospace Research and Development logo

Through a joint effort 2 years in the making, the Air Force, Army, and Navy are funding a Finnish research program established to explore new approaches for improving telecommunications network management. The ultimate goal is to build on this basic research in creating a cognitive network that will use rational decision-making methods to enhance the speed and quality of information delivered via Department of Defense networks.

Researchers previously introduced this "smart" approach in cognitive radio designs, which sought to improve throughput by capturing the best-available spectrum to meet user communication requirements. The problem with applying the current technology "as is" to network management is that modern communications are too complex for it to work effectively.

Researchers anticipate using multiaccess, multimodulation, and (various) multiplexing schemes with heterogeneous network architectures. These networks will not only support multiple product types and ubiquitous services, but will be adaptable to regional spectrum allocation schemes. For a cognitive network to become a reality, researchers must develop new methods, metrics, and intelligent-agent-controlled routers to extend cognitive approaches to full network management.

The European Office of Aerospace Research and Development (R&D) is funding research taking place in Oulu, Finland. The research explores the use of multimodal quality-of-service metrics and negotiated control algorithms to optimize data flow by enabling the intelligent agent to assign priorities among different applications, users, or information.

For more information contact
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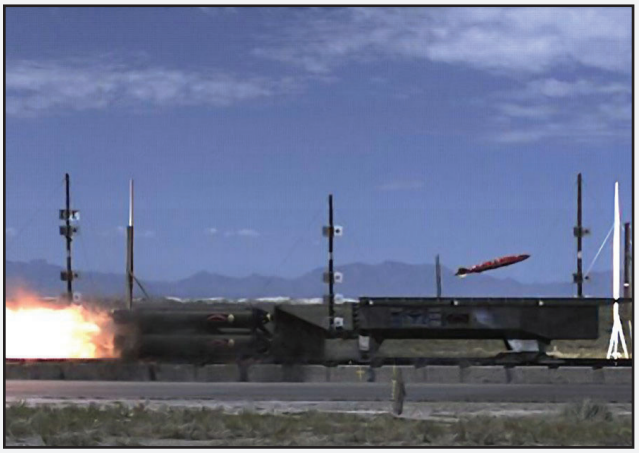
Basic Research Key to Successful Supersonic Bomb Release

AFRL-funded research of active flow control capabilities ultimately played a crucial part of the first-ever supersonic test release of an air-delivered munition. The successful event—which demonstrated the safe release of an MK-82 Joint Direct Attack Munition (JDAM) test vehicle from a weapons bay at Mach 2, or twice the speed of sound—occurred at the 10-mile-long Holloman High-Speed Test Track, Holloman Air Force Base (AFB), New Mexico. The research team completed the effort as part of AFRL's High-Frequency Excitation Active Flow Control for Supersonic Weapon Release program, otherwise known as HIFEX.

In seeking a reliable way to stabilize the weapon on the rocket sled throughout the high speed release, the researchers turned to a supersonic microjet actuator array developed for an earlier AFRL program. The microjet technology was a direct result of the lab's 1999 funding of researchers at two different Florida universities—Florida A&M University (FAMU) and Florida State University (FSU) College of Engineering. The academic research explored the use of supersonic microjets for flow control in applications associated with short takeoff and vertical landing (STOVL) aircraft.

The Florida-based team's specific flow control approach involved the arrangement of supersonic microjets, or nozzles, around a STOVL jet flow to minimize disruption at takeoff and landing. A team from the Massachusetts Institute of Technology joined the effort and subsequently helped to develop the control scheme governing how and when the microjets would fire.

Not long after this AFRL-sponsored endeavor began, the Defense Advanced Research Projects Agency (DARPA)—as the initiator of the HIFEX program—requested that the FAMU-FSU team collaborate with Boeing to apply the microjet research towards the HIFEX goal of achieving safe weapons dispense at supersonic flight speeds.

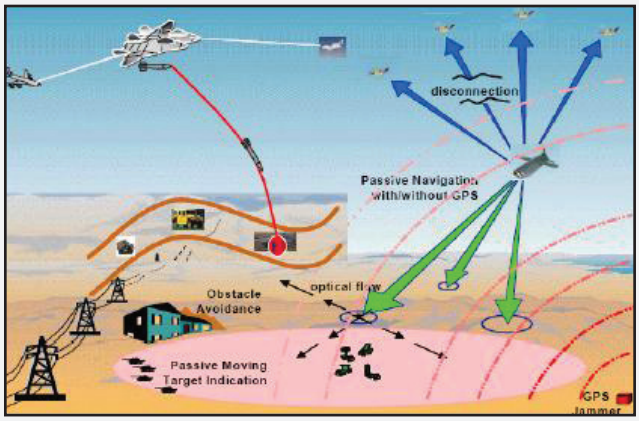


Researchers at the Holloman High-Speed Test Track (Holloman Air Force Base, New Mexico) succeed in accomplishing the first-ever test release of an MK-82 JDAM on a rocket sled traveling at supersonic speed—Mach 2 (image courtesy of Air Force and Boeing).

The supersonic microjet actuator array originally developed for STOVL applications proved a workable solution for high-speed munitions release as well. Specifically, the research team found that placing the microjets upstream of the weapons bay reduced unsteady pressures inside the bay and modified airflow outside the bay, ensuring that the JDAM test vehicle flew out of the rocket sled on a proper nose-up trajectory.

The HIFEX program transitioned from DARPA to AFRL as the effort matured to a full-scale rocket sled demonstration. Researchers will conduct additional full-scale JDAM tests at Holloman AFB as further developments occur.

Innovative Approach for Enhanced Navigation and Seeker Exploitation



Graphic depicting innovative approach for enhanced navigation and seeker exploitation

Researchers from AFRL and Northrop Grumman went on the OFFENSE, developing an innovative approach based on the use of optical flow for [achieving] enhanced navigation and seeker exploitation. The method works to adaptively fuse, in real time, all available navigation data—including that derived from inertial measurement unit/Global Positioning System (GPS) inputs, altimeters, star tracker devices, passive imaging sensors, and digital elevation databases. Accordingly, the novel approach permits continuous navigation throughout non-GPS environments, while yielding improved exploitation in the presence of GPS. The technique also reduces target location error and provides moving target indication.

A critical need exists for a fully autonomous and robust navigation capability in GPS jamming or signal interruption environments. While GPS plays an important role in the guidance and navigation of small munitions and unmanned air vehicles by providing positional updates—which, in turn, bound the drift of onboard inertial navigation systems—it is nonetheless susceptible to jamming and is also unreliable (or unavailable) in urban canyons and indoors. The US Air Force, Navy, and Army are thus keenly interested in a capability that reduces the vulnerability of GPS navigation to interruption—whether deliberate or unintentional.

Scientists dedicated to the pursuit of computer-enhanced vision technologies have witnessed many approaches for computing "ego-motion," which refers to the (sensor or biological organism) observer's movement. AFRL's newly devised approach to navigation exploitation computes ego-motion using optical flow measurements to estimate observer movement. Optical flow, defined as the apparent motion of brightness patterns, is characterized by a field of two-dimensional (2-D) velocity vectors. These 2-D vectors are, in fact, projections of the surface points' three-dimensional (3-D) velocity vectors onto the image plane. The 2-D velocity vectors are derived from image sequences that can then be used for inferring the 3-D velocity of the imaging platform. Since optical flow is a projection of a 3-D velocity vector onto a 2-D image plane, there is inherent ambiguity in inferring 3-D velocity. The observed optical flow must therefore be fused with other measurements—depth, for example—to remove ambiguity and provide an estimate regarding the 3-D velocity vector of the imaging platform. Knowing the observer velocity vector and the last (most recent) GPS position estimate will, in theory, enable navigation in non-GPS environments.

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High-Altitude Return Vehicle Completes Phase II Tests

The AFRL-sponsored Phillips Technology Institute (PTI) successfully completed Phase II of a three-phase test plan for the High-Altitude Return Vehicle (HARV). Phase II employed a balloon-launched, tactical operations payload in a small, recoverable unmanned air vehicle (UAV). Objectives included validation of autonomous navigation from stratospheric altitudes of 65,000 ft to a programmed landing point; simultaneous control of two UAVs; continuous communications handoff capability; and communications repeater, video payload, and other system operations at altitude. Activities performed during Phase I and Phase II involved a pair of UAVs designed and programmed across 14 flights. The experiment is a collaboration between AFRL, PTI, Air Force Space Command, and Arcturus UAV.

Theater commanders require quick-response, loiter-on-station sensor, and communications support, currently provided from a balloon-launched payload system flying from 65,000 to 325,000 ft. However, the unretrievable payloads are destroyed upon impact, a loss of several thousand dollars per flight. Consequently, operators requested development of a payload return upgrade. AFRL scientists responded with the cost-effective option of a 10 ft wingspan UAV with a 20 lb payload capacity, delivered via hand-launched polyethylene balloons. Although HARV employs autopilot software to return it safely to a programmed location, portable ground control stations permit in-flight plan changes, with turnaround times of less than 20 min.

HARV launch stand and balloon

Missions are conducted while the UAV remains attached to the balloon or airship, with a repeater permitting contact between ground stations and satellites. A release mechanism permits the UAV to detach—and then land—with only the loss of the disposable balloon or aerostat. Phase I of the three-phase test activity concluded in December 2006, by which point HARV had successfully demonstrated multiple balloon launches and returns from a 25,000 ft maximum elevation. Phase II has now validated returns from elevations of 65,000 ft. In Phase III, HARV will use an aerostat rather than a balloon. Goals for Phase III include establishing the capabilities of weeklong stationkeeping, long-range communications relay, and simultaneous utilization of multiple payload systems. Phase III planning is under way.

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ManTech Effort Facilitates Increased Production Capability for Joint Programmable Fuze

A B-2 aircraft drops a JPF-equipped Joint Direct Attack Munition.

The JPF

AFRL is in the midst of executing the newest phase of an in-progress Manufacturing Technology (ManTech) effort with the Air Armament Center and industry partner TechSolve. This ongoing collaboration, which focuses on implementing lean manufacturing processes for joint programmable fuze (JPF) production facilities, arose as part of the ManTech Industrial Preparedness Program (IPP). ManTech's IPP works to establish government/industry alliances fostering the expansion of US industrial base capabilities that support the warfighter. In helping to introduce or augment domestic resources of this nature, the IPP assists in reducing systems acquisition and sustainment costs, production cycle and delivery timelines, and risks related to fielding new capabilities. In terms of this particular IPP-based effort, the availability of multiple JPF suppliers with full-scale production capabilities ultimately heightens warfighter access to critical munitions technology.

In April 2003, the Air Force and TechSolve helped Kaman Precision Products build a JPF production system based on lean manufacturing concepts. Kaman continues to function as prime contractor—and, thus, critical component supplier—for the JPF today. Compatible with several types of weaponry—including the Joint Direct Attack Munition—the JPF technology uniquely combines arming and detonation functionality in a single fuze. It is likewise the only fuze that warfighters can electronically reprogram from the cockpit. Consequently, the device has become the "fuze of choice" in far-reaching conflicts such as Operations ENDURING FREEDOM and IRAQI FREEDOM.

An earlier stage of this effort culminated with First Article Acceptance Test, the process by which end-product effectiveness undergoes evaluation throughout the move into production. Since the advent of the latest program phase, the focus has shifted to increasing production capacity—a necessity that, at turns, has prompted two major layout changes; a decision to outsource fuze subassemblies; the start-up of a second production facility; and, most recently, direct engagement with critical supply-chain counterparts involved at various levels of the process. This period marks a crucial turning point for the program, with greater production capacity paving the way to the next level of industrial capability.

Largely a result of ManTech-driven oversight, the manufacture of JPF devices currently achieves quantities approaching full-rate production. Future efforts between AFRL and its applicable partners will continue to pursue maximized production capacities and minimized production costs and cycle/delivery windows. Additional benefits stemming from such continuing efforts may include improved unit quality and reliability as well.

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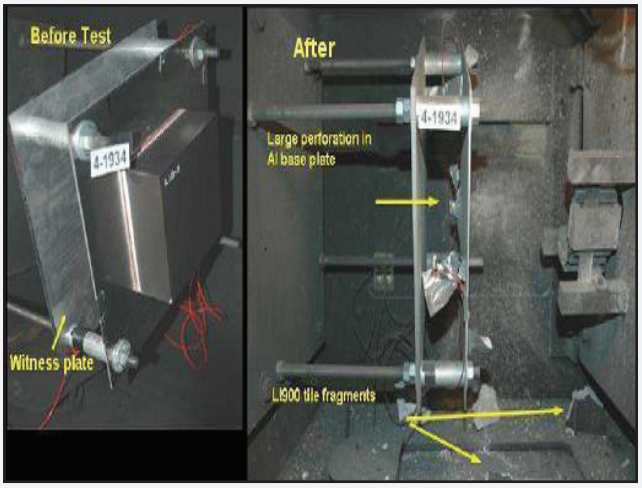
Thermal Protection System Tests Validate Tile Concepts

AFRL recently conducted a series of thermal protection system (TPS) tests aimed at determining the performance and durability of various TPS tile concepts under extreme environmental conditions. Researchers are developing concepts wherein various ceramic matrix composite (CMC) materials are wrapped around silica-based insulating tiles to increase tile durability and decrease maintenance requirements. Researchers conducted micrometeoroid orbital damage (MMOD) testing at the University of Dayton (Ohio), evaluating oxide-CMC- and nonoxide-CMC-wrapped tiles in order to determine which variation performed best under projectile impacts of 7 km/sec. They performed a second set of tests in AFRL's Combined-Environment Acoustic Chamber (CEAC), evaluating the performance of the similarly wrapped tiles under simulated launch and reentry thermal and acoustic conditions.

The MMOD tests revealed that high-density (14 lb/ft^3) tiles with an oxide CMC wrap or a carbon silicon carbide (C/SiC) wrap performed best; in both variations, the tile wrapping was totally shattered but the base plate (representing the surface of the vehicle skin) was completely undamaged. As a baseline measurement, the researchers also tested unwrapped tiles, similar to some of those used on the space shuttle. These tiles failed to provide adequate damage protection, leaving a 1in. hole in the base plate. All wrapped tiles that were tested outperformed the baseline (unwrapped) tiles.

During CEAC testing, researchers subjected an array of eight wrapped tiles to thermal conditions ranging from 800°F to 2300°F and acoustic levels up to 165 dB. The array included a single unwrapped tile (which served as a control), two C/SiC-wrapped tiles, and five oxide CMC tiles. Test results showed that the oxide CMC tiles performed best, experiencing no delamination or loss of tile faces.



Baseline space shuttle TPS tile

Overall results of the test series indicate that oxide-CMC-wrapped tiles offer superior performance under all simulated environmental conditions. CMC-wrapped tiles represent an attractive option for TPS components because they provide an outer covering that is extremely durable and a foam interior that is very lightweight. Once the data from this test series has been compiled into a final report, scientists will use it for ongoing TPS research. Ultimately, the project's goal is to offer a durable, low-maintenance TPS concept for future reentry vehicles.

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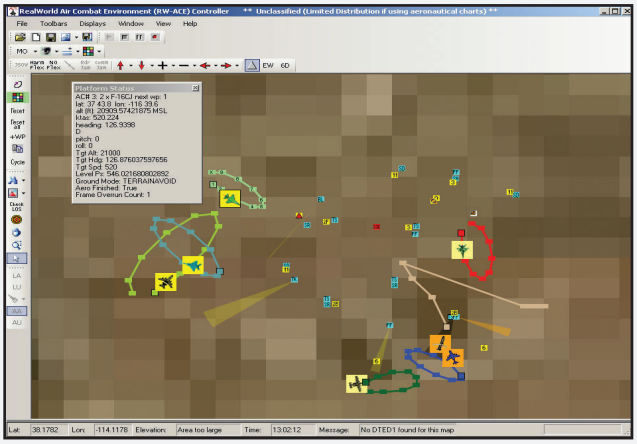
Excess Energy Aerodynamic Model Transitions to DARPA



DARPA's RW-ACE platform graphic

AFRL transitioned its high-fidelity, high-entity-count Excess Energy aerodynamic software model to the Defense Advanced Research Projects Agency (DARPA) for use in the agency's Real-World Air Combat Environment (RW-ACE) simulator program. Employed by the 563rd Flying Training Squadron (Randolph Air Force Base, Texas), the RW-ACE simulator enables up to ten weapon system officers and aviators to fly concurrently in the same battlespace just as they would in combat, reacting to threats and interacting with different Air Force platforms as displayed on a common screen.

The aerodynamic model currently incorporated in the RW-ACE simulator is extremely limited, incapable of representing more than just a few performance distinctions between heavy bombers, fighter aircraft, and cargo planes. Though other high-fidelity models are available, they can handle only a small number of aircraft at one time. Having encountered similar issues while developing XCITE, the eXperimental Common Immersive Theater Environment computer-generated-forces software, AFRL subsequently designed and developed an Excess Energy aerodynamic software model. The new model does more than accommodate a significant number of participants; it also alleviates the problem of unrealistic aircraft characteristics by leveraging National Air and Space Intelligence Center–produced aircraft data to provide plausible turn, acceleration, and climb performance data at varying altitudes and speeds.

Because engineers based the Excess Energy aerodynamic model on the idea of high-entity-count distributed mission operations, it has the capacity to fly hundreds of aircraft (built on 50 different airframes) on a single personal computer. To prepare the technology for transition to DARPA, AFRL reengineered the Excess Energy model to function as a stand-alone module. Overall, the DARPA-specific customization required fewer than a dozen lines of modified software code. Students flying with the RW-ACE simulator's newly incorporated Excess Energy module will now have a realistic environment in which to train.

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Researchers Develop Cognitive Training Tool for Military Deception Planning

Air Force SBIR/STTR

AFRL-funded researchers from Aptima, Inc., teamed with personnel from Headquarters Air Force and Headquarters Air Combat Command for a Small Business Innovation Research (SBIR) effort to develop and transition a cognitive tool for training military personnel on the process of tactical military deception planning. The cognitive tool aids these individuals in learning to organize and structure work products that support the development of effective deception plans. Accordingly, the new tool supports the creation of visual representations depicting organizational functions, processes, and communication pipelines in flowchart form. Further, it automatically translates this flowcharted information into event checklists displayed in tabular form, simultaneously performing automated consistency checks between flowchart and checklist elements.

39th Information Operations Squadron logo

Novice military deception officers and noncommissioned officers routinely encounter difficulties in maintaining a clear-cut mapping of the deception planning process, from the original tasking to the specific sequence of steps constituting the deception plan execution checklist. Common problems include a lack of plan consistency, completeness, plausibility, and/or proper attention to intelligence threats. The SBIR-developed training tool helps to mitigate these issues, while also enforcing compliance with base profiling procedures. The Air Force Information Operations Center, 39th Information Operations Squadron (Hurlburt Field, Florida) will incorporate the training tool into a new signature management course by early 2009.

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Lab Assists in User Evaluation of Vehicle Inspection System

A sport utility vehicle parks on ramps that permit MUVIS to photograph its undercarriage.

AFRL engineers traveled to Elmendorf Air Force Base (AFB), Alaska, to assist in the user evaluation of the Mobile Under-Vehicle Inspection System (MUVIS), a system designed to reduce the danger military personnel face while performing under-vehicle searches for explosives. MUVIS allows its operator to maintain a safe distance from the vehicle being inspected. This capability enables personnel to get a direct, close-up view of vehicles without being placed in a potentially dangerous situation.

Developed under a contract with Kachemak Research Development (KRD) and managed by AFRL engineers, MUVIS consists of metal ramps, a high-resolution camera, and a laptop computer. Vehicles drive directly onto the ramps, and the camera (which is mounted between the skids of these ramps) moves the length of the vehicle, photographing its undercarriage. The inspection system operator, who can remain at a distance of his or her choosing, uses the laptop to review the resulting high-resolution images. As necessary, the operator can zoom in on any part of the undercarriage that requires closer inspection.

The team conducting the system evaluation at Elmendorf AFB comprised AFRL engineers, active duty personnel from the 3rd Security Forces Squadron, and personnel from the Naval Surface Warfare Center's Crane Division. Engineers from AFRL and KRD first trained the squadron and division personnel on MUVIS operation; these trained users then provided feedback geared towards system improvement. During the evaluation, MUVIS scanned and imaged 223 vehicles with no system failures. Thus far, system performance has surpassed all expectations.

AFRL and KRD engineers documented all suggestions and observations. In the future, the program will focus on the development of a similarly intended Large-Vehicle Inspection System, with the team that evaluated MUVIS most likely evaluating that future system as well.

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Comprehensive Integrated Defense Analysis Improves Security

AFRL researchers developed a new methodology for assessing security risks and are now in the process of developing Force PRO, a supporting software tool. AFRL's newly established methodology and companion software transform traditional vulnerability assessment into a true risk management process. The new methodology, intended for use at all military installations, accomplishes key elements of the Installation Antiterrorism program as required by Department of Defense and Air Force standards. Focused on risk reduction solutions instead of merely problems, it brings simplicity and efficiency to a formerly tedious, time-consuming process. In addition, the new methodology complies with current installation antiterrorism standards and also generates installation-specific feedback, promoting safer, more cost-efficient military installations.

The AFRL-developed risk assessment methodology encompasses effects-based security, an approach that considers each base's risks, locally and individually, and subsequently employs security tactics, techniques, and procedures specific to that base and its assets. The methodology thus helps installation security officers answer three basic questions: (1) What are this installation's key assets? (2) What genuine threats exist that can damage or destroy these assets? and (3) What current vulnerabilities could allow these threats to successfully attack each asset? By answering these questions in an organized manner, the security officers can not only determine which threats and tactics present the most risk, but also tailor their security activities towards mitigating those risks.

Air Force security flyover

To facilitate a less time-consuming and more accurate security risk assessment process, the AFRL researchers developed a Microsoft Access database program that assigns standardized numerical values to each asset, to each threat to that asset, and to each vulnerability allowing an attack against the asset. Using these numerical values, the program then calculates the specific installation's risk factors, ranking them in order from risks that are totally unacceptable and must be reduced to risks that are tolerable. Armed with this information, base commanders can make informed decisions regarding where to spend money and how to best direct other resources to improve security.

To date, AFRL researchers have used the new methodology to perform security risk assessments at 14 government installations, including the Statue of Liberty. They have received positive feedback and are currently working to develop an advanced software tool that security officers will be able to use on their own, so that no visit from outside specialists is required.

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Urban FAST Sensor Capabilities Demonstrated

Pictures from the Urban FAST program

Engineers from AFRL and the Mustang Technology Group teamed for a Phase II Small Business Innovation Research effort to develop and test Urban Fuze Air-to-Surface Technology (FAST). Urban FAST is a precision height-of-burst (HOB), ground-profiling fuze sensor capable of engaging targets in urban terrain. Regardless of target structure and background, AFRL's Urban FAST sensor can accurately discriminate true ground height from surrounding structures, enabling accurate HOB weapons operation. The sensor technology has demonstrated its capacity to operate effectively in urban environments and will significantly reduce the potential for collateral damage associated with employing ordnance in those densely structured and populated areas.

The test team designed and constructed an innovative urban scenario, using shipping containers as structural bases and reconfigurable wooden modules stacked atop the containers to vary structural height. The test airframe housed the Urban FAST sensor, antenna, and hardened data recorder. The team executed a total of ten parachute drops and two functional drops over the mock town. Conducting low-cost drop tests over such a mock-up enabled researchers to collect data representative of an actual urban area, verifying both Urban FAST sensor system performance and predictions of discrete ground structure reflectivity. The drop test results proved Urban FAST's accuracy in extracting ground elevation data throughout the weapon's operation in proximity to discrete structures. Subsequent data analysis identified what algorithm and simulation adjustments would be necessary for perfecting radar algorithms and preparing Urban FAST for drop testing in an actual tactical scenario.

Weapons with precision HOB accuracy are crucial to military operations conducted in urban terrain, wherein the risks to nearby civilians and friendly forces and the potential for collateral damage are far greater than in other environments.

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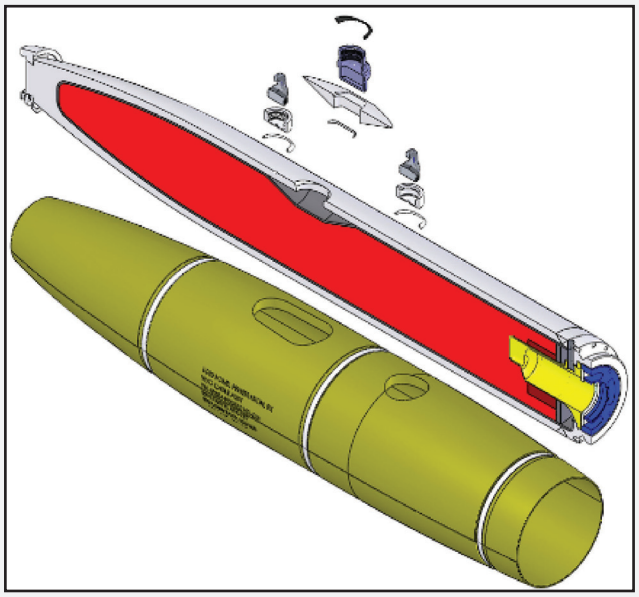
Computational Analysis Improves I-500 Warhead Survivability

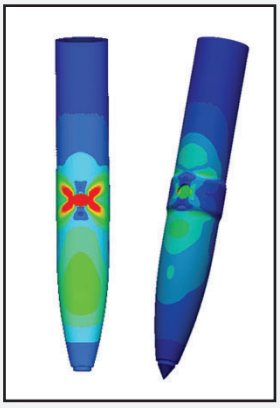
AFRL engineers conducted dynamic computational analysis geared towards improving the survivability of a proposed I-500 warhead design. The intent of this warhead is that it provide hard-target penetration capability while duplicating the properties of mass (i.e., the 500 lb weight); the external dimensions; and the external interfaces that are hallmarks of the Mk-82 general-purpose bomb. By designing the I-500 weapon according to these constraints, engineers were able to forego the flight certification process required for new warheads, decreasing both program costs and the time needed for transitioning the technology to the warfighter. The advanced computational analysis methods employed for this effort enabled assessment of the warhead's performance throughout its penetration of a hardened target.

The I-500 concept consists of a hardened penetrator encased in a lightweight composite shroud that captures the outer moldline of the Mk-82. It also includes an arming well cut into the side of the penetrator's steel casing in order to accommodate standard cable attachments for fuze arming and thereby match existing external interfaces of the Mk-82. AFRL's dynamic structural analysis of the I-500 predicted that significant localized deformation around the arming well hole would occur during oblique penetration into a hardened concrete target. Such deformation would indicate a very high risk of warhead case fracture, an event likely to precipitate catastrophic systems failure.

Based on these results, AFRL engineers subsequently redesigned the I-500 for enhanced survivability. In order to mitigate the risk of structural failure during penetration, AFRL's design improvements included recommendations to locally increase case thickness near the arming well hole (providing extra stiffness), repackage the fuze-arming unit inside the arming well (reducing the hole's diameter by approximately 20%), and add a tip to the originally blunt nose (decreasing deceleration loads during penetration). Ongoing computational analysis suggests that these changes should significantly increase the warhead's structural survivability during its penetration into hardened targets.



Design concept for the I-500 warhead



I-500 warhead's predicted deformation contours after penetration into hardened concrete: original design (left) and AFRL-proposed design (right)

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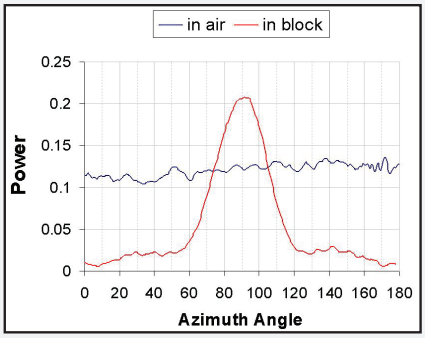
Demonstrated Metamaterials Technology Transforms Antenna Radiation Pattern

Dipole antenna inserted into AFRL's near-zero [refractive] index material



While radiation emitted from a dipole antenna into free space (blue line) has no directionality, radiation emitted from a dipole inserted into a NZIM radiates strongly in the direction perpendicular (at a 90° azimuth angle) to the NZIM.

AFRL researchers demonstrated the capacity of electromagnetic metamaterials to tailor antenna radiation patterns. Metamaterials have inherent properties not present in naturally occurring materials. This distinction usually stems from the way in which a given metamaterial's constituents are structured. The researchers designed and fabricated a block of "post and split-ring resonator" metamaterial that, with its microwave frequency of nearly 13.8 GHz, has a refractive index that is close to zero.

Refractive index is a measure of how a particular material bends and/or reflects electromagnetic radiation (including microwaves or light waves) impinging upon it. For "normal" materials, such as glass, this index is greater than 1; for air, it is almost exactly 1. Near-zero index materials (NZIM) do not exist in nature; radiation emitted from these manufactured materials into the surrounding air must exit in a direction essentially perpendicular to the NZIM.

The AFRL research team exploited this NZIM characteristic to transform properties of the well-known dipole antenna (which is similar to the stick-type antenna on many automobiles). The demonstrations showed that while the microwave radiation emitted from a dipole antenna into free space has no directionality, the radiation emitted from a dipole placed inside the NZIM radiates strongly in the direction perpendicular to the plane of the metamaterial. This phenomenon is the opposite of what happens with optical fibers—which, with refractive indices greater than 1, trap and can thus "guide" light. This unusual result indicates how further research on metamaterials-based antenna combinations may lead to surprising and useful radio frequency components.

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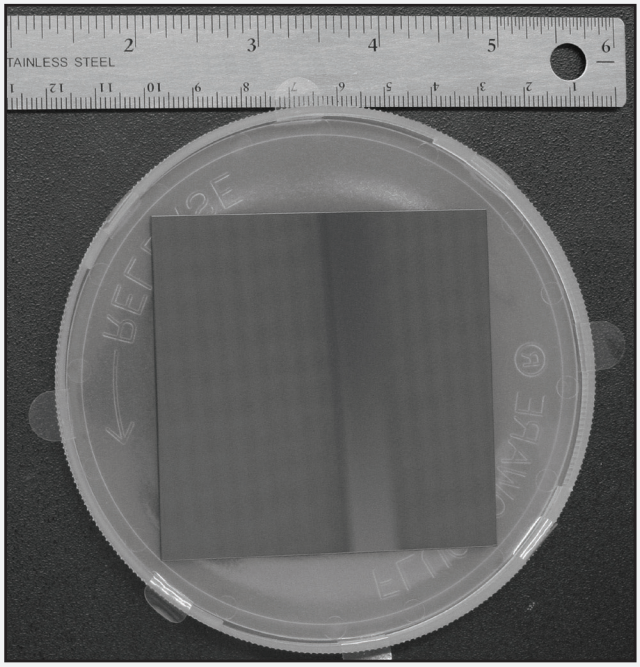
Geodesic Dome Phased-Array Antenna Program Receives AFRL Sponshorship

To support Air Force Space Command's management of the Air Force Satellite Control Network (AFSCN), AFRL and the Space and Missile Systems Center are jointly sponsoring the Geodesic Dome Phased-Array Antenna (GDPAA) Advanced Technology Demonstration (ATD). Part of a multiphase activity to upgrade AFSCN assets, this ATD addresses replacement of the large dish antennas currently in use throughout the network. The switch to GDPAA technology will greatly improve satellite communication links, providing the Air Force with more flexible and reliable satellite telemetry, tracking, and control capabilities. To realize these enhancements, AFRL initiated a contract with Ball Aerospace to prepare a top-level design for a future GDPAA and to build and test a phased-array antenna as an ATD substantiating the decision to pursue—and the capacity to achieve—a full-fledged GDPAA.

GDPAA

High Stare Program Achieves Preliminary Design Review Milestone



High Stare, a high-performance, large-format shortwave-infrared focal plane array

High Stare is an AFRL program aimed at creating the larger infrared sensors that future missile warning systems will require. Accordingly, the 5-year effort is specifically focused on developing high-performance, large-format, shortwave-infrared focal plane arrays. Industry partners Teledyne Imaging Sensors and BAE Systems, each of which holds a contract with AFRL for completing specific technology development activities, successfully met the program's important Preliminary Design Review milestone. The advanced design associated with High Stare systems is intended to reduce the complexity, weight, power, and—ultimately—cost of tomorrow's missile warning satellites.

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Researchers Develop Lightweight Next-Generation Airfield Matting System

Researchers from AFRL and Webcore Technologies, Inc., made significant headway in the design and development of a strong, lightweight-composite-based airfield matting system for forward aircraft deployments. The next-generation matting system touts a 36% weight reduction over the extruded aluminum (AM-2) panels currently in use and has twice the operational life. The lightweight system's simple connection method and optimized shipping size will enable the Air Force (AF) to deploy aircraft more rapidly via considerably faster expansion of parking aprons and connection of taxiways and maintenance areas. Several years of extensive testing and analysis have effectively demonstrated that the new matting system meets loading and weight requirements.

The AF's renowned capacity to respond quickly and decisively anywhere in the world relies on myriad combat support activities that occur on the ground. Typical deployments to remote locations require a large number of aircraft sorties to transport equipment, personnel, and supplies. As a military operation intensifies, the available taxiways, parking space, and aircraft maintenance areas are quickly exhausted. Conditions range from extremely austere dirt strips to commercial airports and fixed military installations. Parking aprons at many of these potential airfields are not adequate to support large contingency operations, a problem further complicated by the fact that the soil types at many sites are unknown.

Maximum-on-ground (MOG) requirements represent a major aspect of assessing airfield capabilities. MOG assessment entails two categories: parking and working requirements. Whereas parking MOG refers to the number of aircraft that can be parked at an airfield and is dependent on the specific mission, working MOG is based on the available parking space, the size and type of crews, and the equipment available to service aircraft. Working MOG thus has significant impact on the overall speed at which a bare base can be established.

Tests of weight-bearing capacity being conducted using a load cart

Increasing MOG capabilities at airfields supporting forward military deployment operations is essential. This is why AFRL engineers, in conjunction with Webcore Technologies, have undertaken to design and develop a new composite airfield matting system that addresses not only technological issues, but cost savings concerns as well. Composite materials are up to ten times stronger than conventional matting materials but weigh considerably less. In significantly advancing the AF's capability to perform contingency operations from bare bases and austere airfields, composite airfield matting systems will have an immediate and positive impact on mission success. To further improve the new system's performance, AFRL researchers are continuing research and development efforts geared towards advanced-composite hybrid material concepts.

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Transportable Waste-to-Energy System Produces Electricity

AFRL's TWES

AFRL researchers are developing a transportable waste-to-energy system (TWES) to produce electricity from renewable energy, in this case recycled waste, at forward military operating locations. The Department of Energy's Federal Energy Management program is supporting the effort. By reducing the amount of fossil fuels required at military installations, AFRL's TWES will reduce both the cost and the environmental impact associated with generating electricity. Further, the system's consumption of combustible waste will minimize reliance on outside contractors for waste disposal, as well as assist Air Force compliance with key environmental goals and standards.

AFRL researchers have completed construction of the system's first stage, the transportable furnace system (TFS), and installed it on a 48 ft long, flatbed semitrailer. Before the furnace can burn solid waste, it must be preheated with a Beckett fuel burner, using either diesel or JP-8 fuel at a rate of around 5 gal/hr. This type of burner is commonly used for heating buildings and performing industrial processes.

The TWES functions as follows. Bulky solid-waste items, such as wood, pallets, paper, plastics, and yard clippings, are dropped into a material holding compartment (i.e., a hopper) on the shredder to await processing. Next, the shredder reduces this material to scraps of less than 1/2 in. in all three dimensions. The shredded waste material then falls into a box from which it is subsequently vacuumed through a large, flexible hose and into a second hopper. From there, the material drops through a rotary feeder and into a pipe with air blowing through it. The rotary feeder helps measure the amount and speed at which the shredded waste is pneumatically conveyed into the furnace. The shredded waste flows steadily from the pipe into the preheated furnace, where it essentially becomes fuel, heating quickly and bursting into flame.

The energy generated from the burning fuel maintains the furnace temperature, sustaining the combustion process for additional shredded waste that continues to enter. The burning waste swirls through the furnace, and the resulting exhaust rises through the exhaust stack. During testing, the TFS burned wood at a rate of 150 lbs/hr. Stack emissions were clear, with no visible smoke, and an inspection inside the furnace confirmed no residual soot.

AFRL researchers recently began the second stage of this project, designing the system's energy recovery component. Using a series of heat exchangers, this component will generate steam using the heat released from the burning waste. Potential uses of this steam energy include heating, absorption air conditioning, and electricity generation for forward operating bases and/or rural domestic bases. The prototype system will generate electricity with the functional capacity of a small power plant. When completed, the TWES will burn up to 500 lbs of waste per hour.

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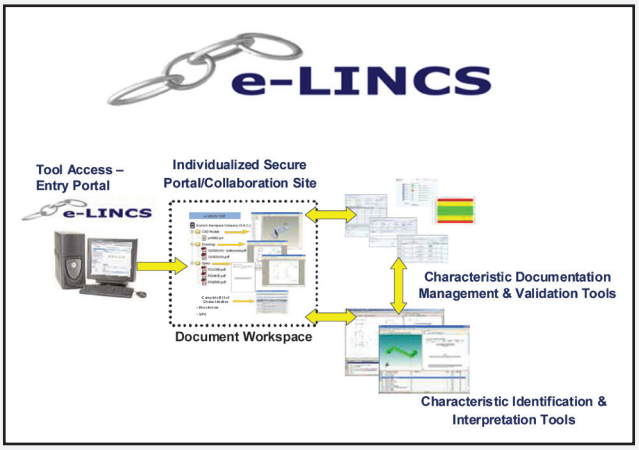
e-LINCS Advances Information Technologies for Aerospace and Defense Suppliers

AFRL engineers recently concluded an effort culminating in the establishment of e-LINCS, an "Electronic Industry-Wide Network for Characteristics and Specifications." The premise of the e-LINCS initiative was to establish a set of universally accessible tools facilitating the flow of detailed technical requirements to every level of the aerospace and defense supply chain. Implemented as a fully electronic, Web-based service, e-LINCS enables suppliers to extract relevant portions of their customers' design intent at the characteristic level, translate that information into hardware, and flow the results back to the prime level. The availability of e-LINCS will assist aerospace and defense suppliers in achieving greatly reduced cycle times, enhanced productivity, and substantially improved product quality.

The management, flow, and interpretation of technical requirements—while a seemingly mundane facet of the aerospace and defense equation—has emerged as one of the greatest challenges the aerospace and defense supply chain faces. The e-LINCS program therefore arose from a variety of underlying dynamics, such as the shifting nature of that supply chain (which places increasing responsibility on lower-tier suppliers), the uncompromising demand for quality at all levels (including elements of the extended supply chain), the growing complexity of new technical requirements, and the poor preservation of legacy technical data.

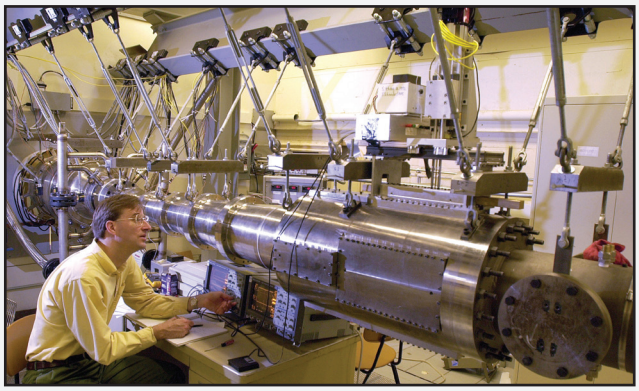
Industry partner Renaissance Services aided AFRL in formulating the 4-year e-LINCS technical effort. Leveraging a number of emerging electronic tools and Web-based systems, the company determined what tools were needed to "unlock" technical data content, integrated other desirable system features, and ultimately delivered the resulting



AFRL e-LINCS program logo and process diagram

e-LINCS system as a universally accessible supply chain resource. The unique combination of advanced information technologies used in constructing e-LINCS renders it capable of electronically unlocking vital design characteristic and specification data; removing data ambiguity; and, consequently, enhancing understanding at every level of the supply chain. AFRL's e-LINCS technology is readily accessible and affordable to the thousands of small and midsized producers who together form the backbone of the US aerospace and defense industrial base. Numerous e-LINCS users have already cited productivity gains of 50% to 90%.

University Researchers Use Lab-Developed Wind Tunnel for Hypersonic Testing



AFRL/Boeing Mach 6 Quiet Wind Tunnel

AFRL funded the research that ultimately produced the world's only quiet hypersonic wind tunnel. Purdue University researchers are now using this unique resource to test the performance of vehicles traveling at hypersonic speeds (i.e., approximately 4,000 mph). The research team, led by Purdue's Dr. Steven Schneider, is using the AFRL/Boeing Mach 6 Quiet Wind Tunnel to study the flow of air over the nose of the X-51A, a new hypersonic vehicle prototype.

Specifically, the team is compiling information detailing when and how airflow changes from laminar (i.e., smooth) to turbulent as it speeds over X-51A surfaces. Dr. Schneider notes that smoothing the flow of air over the aircraft's upper surface is important because doing so reduces friction and heat that could potentially destroy the vehicle. The transition from laminar to turbulent airflow can precipitate a tenfold increase in surface heat.

Achieving the quiet test environment requires that the curves of a tunnel segment called the nozzle be modified, and its surfaces subsequently polished to a mirrorlike finish. These conditions delay the onset of turbulent flow in the nozzle, so that airflow entering the test section is as quiet and smooth as possible. In a conventional wind tunnel, turbulent flow in the nozzle radiates noise into the test section, potentially interfering with—or masking—critical findings.

By leveraging the novel research capability made possible by the Mach 6 tunnel, Dr. Schneider's team is able to investigate the impact of airflow on vehicles such as the X-51A, characterizing the onset of the transition from laminar to turbulent airflow with a clarity that would be impossible using a conventional wind tunnel.

The team has been perfecting the wind tunnel for over a decade. The National Aeronautics and Space Administration pioneered quiet facilities many years ago, but Purdue University maintains the only such facility in the world capable of operating at hypersonic speeds.

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Demonstrations/Exercises

UAV Prototype Tested at Northern Edge 2008

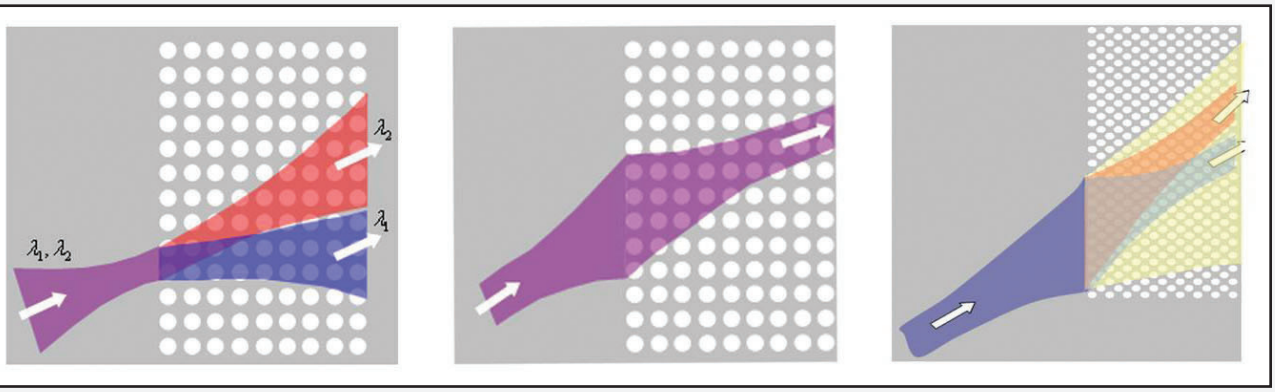
Thanks to lab-generated advances in small, unmanned reconnaissance aircraft technology, military personnel positioned on the ground may be able to get an inside track on what lies ahead, literally. AFRL researchers launched the lab's Arcturus unmanned air vehicle (UAV) prototype during Northern Edge 2008, a joint service exercise conducted across various locations of the Pacific Alaska Range Complex and in the airspace over the Gulf of Alaska. Testing performed throughout this large-scale event successfully demonstrated the UAV's capacity to follow movement on the ground, recognize changes in the landscape, and work autonomously.

Arcturus employs a built-in algorithm that enables it to track targeted vehicles with zero man-in-the-loop intervention. Once a controller programs Arcturus for autotracking, the UAV is able to follow vehicles around corners, through turns, behind trees, and so on—all with no further inputs required. As it operates, the UAV captures real-time video and snapshot images for use in targeting, tracking, geolocation, or battle damage assessment. This new technology will give personnel an enhanced, bird's-eye view of the battlespace.

Mr. Red Jensen, chief pilot, prepares to launch the Arcturus UAV at a test site in the Pacific Alaska Range Complex (photo courtesy of Sergeant Rocky Smith, US Marine Corps).

The purpose of the Northern Edge exercise is to provide participants an annual venue for practicing joint operations, techniques, and procedures; improving command, control, and communication relationships among the services; and developing interoperable plans and programs. Over 5,000 participants—representing active duty, reserve, and National Guard units of the US Air Force, Army, Navy, Marines, and Coast Guard—took part in the 2008 event.

Integrated Photonic Structures Will Facilitate Improved Communications and Signal Processing Capabilities



Schematic representation illustrating the three properties of photonic crystals used for wavelength demultiplexing: the superprism effect (left), negative diffraction (middle), and negative refraction (right) (photo courtesy of Dr. Ali Adibi)

An AFRL-funded research team demonstrated the use of integrated photonic structures for increasing communications and signal processing capabilities from different parts of Air Force aircraft. Dr. Ali Adibi — of APEX, the Georgia Institute of Technology's Center for Advanced Processing-tools for Electromagnetic/acoustic Xtals [crystals] — is a central participant in AFRL's nanophotonics program. His photonic crystal concepts will enable the design and realization of a completely new class of devices for advanced military communications and signal processing systems.

The AFRL-sponsored team demonstrated that using higher bands of photonic crystals results in improved performance of those structures. Accordingly, the researchers extended the design of the demultiplexers to create devices capable of receiving a single input that carries many signals and subsequently separating those signals across multiple outputs that, in turn, measure the distribution of optical energy over the wavelength. These devices, called spectrometers, are in high demand for various all-optical sensing applications, including those geared towards detecting harmful gases, explosives, and biological and chemical agents. Having achieved improved demultiplexing performance via the integration of higher-band photonic crystals, the next step is to combine the new devices with other structures to form fully integrated photonic modules for use in sophisticated communications and signal processing functions.

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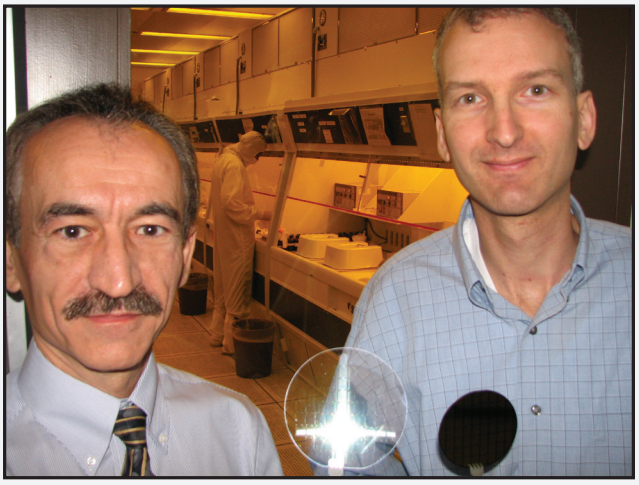
Team Demonstrates Effectiveness of In-House Transparent Transistor Technology

AFRL scientists demonstrated world-record performance of transparent transistors created by a team of in-house sensors scientists. Composed of thin-film nanocrystalline zinc oxide, the novel transistors can function undetected on clear surfaces such as glass or plastic. Lead investigator Dr. Burhan Bayraktaroglu and his team are responsible for developing and testing these transparent devices. The technology's combination of high channel mobility, mechanical flexibility, and high optical transparency at room temperature make it an excellent candidate for supporting a wide range of future Air Force electronics needs.

Potential applications include video image displays and coatings for windows, visors, and windshields; electrical interconnects for integrated, multimode, remote sensing focal plane arrays; high-speed microwave devices and circuits for telecommunications and radar transceivers; and semitransparent, touch-sensitive screens for emerging multitouch interface technologies. Another attractive aspect of this new thin-film type of transistor is that the processing technology used to fabricate the devices is not only relatively simple but also compatible with inexpensive plastic and flexible substrate technology.

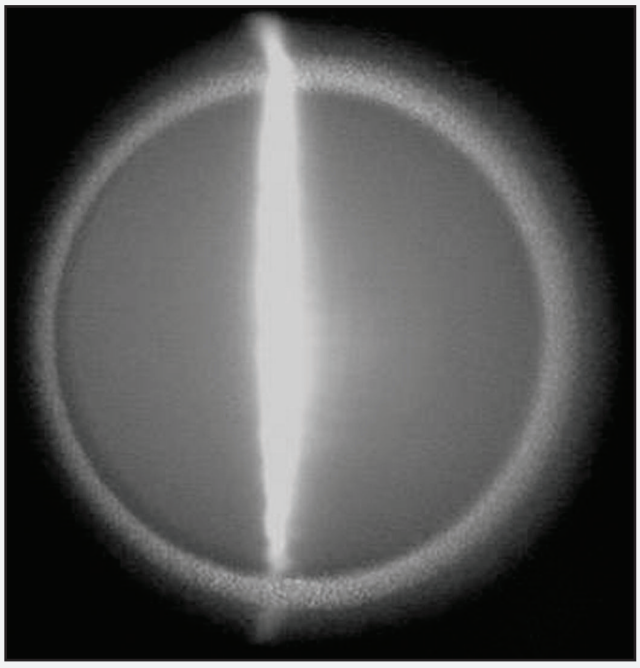
The AFRL team discovered that controlling transistor conductivity and transparency is a matter of optimizing the size and density of constituent zinc oxide nanocrystals. The successfully demonstrated films are 90% to 95% transparent, have metallike electrical conductivities, and can withstand high temperatures for long periods without degrading.



AFRL's Dr. Burhan Bayraktaroglu (left) and Dr. Kevin Leedy (right) contrast transparent electronic circuits on quartz (left) to conventional circuits fabricated on silicon wafers (right) at the lab's wafer fabrication facility.

Dr. Bayraktaroglu and his team have used these devices to demonstrate the world's first thin-film microwave transistor. They have also perfected the application of zinc oxide films onto various surfaces using a special technique called pulsed laser deposition, which employs an ultraviolet laser beam to first remove zinc oxide nanocrystals from a source and then deposit them as a thin film on the desired surface. Through standard lithography techniques, these films then undergo the processing needed to produce field-effect transistors and transparent conductors.

Photonic Modulation Advances Quantum Mechanics



Stanford University researchers potentially advance quantum cryptography, information processing, and memory storage by achieving the first-ever modulation of a single photon's time profile (image courtesy of Dr. Steve Harris).

AFRL-funded researchers at Stanford University have potentially advanced quantum cryptography, information processing, and memory storage by being the first scientists to modulate the time profile of a single photon. Single-photon physics provides secure communication. Coding photons makes eavesdropping impossible, since any attempt to eavesdrop destroys the photon in the process. The researchers, led by Dr. Steve Harris, demonstrated a new technique for modulating an individual photon's wave packet. Their work leverages "cold atoms"—a term coined through the Nobel Prize–winning efforts of Dr. Steve Chu and colleagues to invent a novel technique for cooling atoms. Using "slow light" and electromagnetically induced transparency, the AFRL-sponsored team created an entangled photon wave packet nearly a microsecond long. Prior to this achievement, wave packets were too short to permit modulation.

In working with wave packets, it is important to know when the photon is inside the pulse-shaping device—in this case, the electro-optic (EO) modulator. The researchers determined the particle's location by first generating two photons in rubidium gas at slightly different frequencies and then letting the slow-moving (speed-of-light) photon signal the faster (1/10,000-the-speed-of-light) one's arrival in the EO modulator.

Producing particular wave packet forms previously meant creating single photons in specific cavities. The new approach enables much faster photon modulation than was formerly possible. Likewise, it has the capacity to support phase modulation, which is advantageous in that it causes no loss of photons. While this present work demonstrates amplitude modulation, the team's next stage of research will address the anticipated phase modulation capability. Through this upcoming research activity, the researchers expect to show the feasibility of transmitting many bits of information as part of a single photon's phase.

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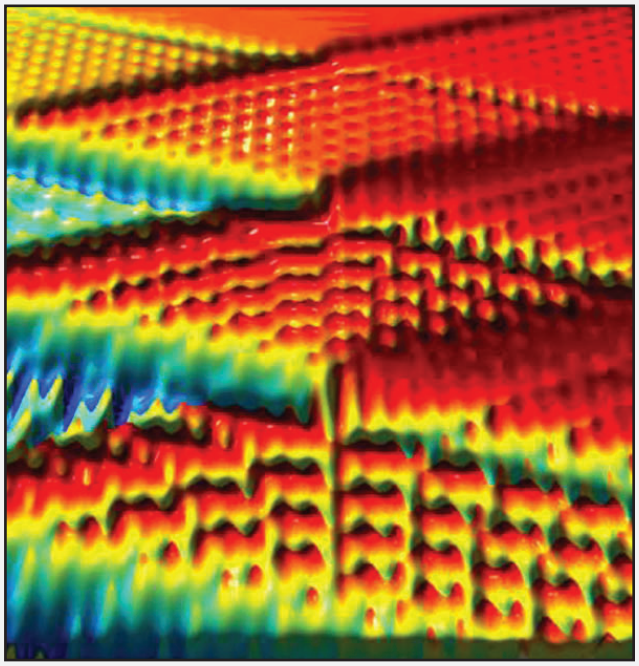
Lab-Funded MIT Research Enhances Quantum Computers

AFRL-sponsored research ongoing at the Massachusetts Institute of Technology (MIT) is accelerating the development of quantum computers. Quantum computing helps the Air Force pursue important capabilities in cryptoanalysis, or "code breaking"; microwave electronics; and materials science. The lab-funded researchers, teamed across the Lincoln Laboratory and the Research Laboratory for Electronics at MIT, developed what they call "amplitude spectroscopy." This technology analyzes an atom's response to different electromagnetic radiation amplitudes at a fixed frequency in order to extract the atom's energy-level structure (spectroscopy) over a broad bandwidth.

The researchers demonstrated amplitude spectroscopy using superconducting artificial atom structures consisting of two superconductors linked by a nonconductive barrier. When the atoms cool to ultralow temperatures via dilution refrigeration followed by microwave-induced cooling (similar to laser cooling for atoms), they exhibit energy levels akin to a natural atom or molecule.

The fabrication of such structures is unique and requires special tools. Whereas most researchers use ultrathin aluminum film to create artificial atoms, the MIT team uses niobium, leveraging a semiconductor-based, multilayer fabrication process that uses optical lithography and chemical-mechanical planarization. One of the key accomplishments of the MIT work is the newfound capacity to fabricate the deep-submicron Josephson junctions necessary for realizing artificial atoms.

As the researchers learn more about these superconducting structures, they will continue to apply this knowledge in furthering quantum computing technology—both for present-day development needs and future possibilities. Meanwhile, scientists can use artificial atoms as the "quantum bits" (i.e., qubits) of quantum computing technology—a challenging, long-term focus area that drives near-term innovations. AFRL has funded several of this same team's successes, which include Mach-Zehnder interferometry in a strongly driven superconducting qubit; microwave-induced cooling of a superconducting qubit; and amplitude spectroscopy of a solid-state artificial atom.



Amplitude spectroscopy generates a unique "fingerprint" of an artificial atom's energy-level structure. This fingerprint comprises quantum interference patterns that form an energy landscape in the space of flux and microwave field amplitude. The peaks and valleys of this landscape take the shape of diamonds and, like a fingerprint, provide a unique snapshot of the atom's energy-level structure (image courtesy of S.O. Valenzuela and W.D. Oliver).

Cooperative Operations in Urban Terrain Program Reaches Important Flight Test Milestone

COUNTER program UAV

AFRL scientists achieved an important milestone in completing a successful flight test for the Cooperative Operations in Urban Terrain (COUNTER) program. The COUNTER project is an effort to provide situational awareness to special operations forces working in urban environments. The COUNTER team uses small and micro unmanned air vehicles (UAV) to perform surveillance and collect video telemetry for detecting possible threat targets in the urban terrain. During the test, conducted at the US Marine Corps Air/Ground Combat Center, a Vigilant Spirit Control Station operator sent three UAVs to inspect potential threat targets hidden in the facility's urban landscape. The UAVs collected video telemetry and transmitted the data back to the operator. This flight test represents the first time that three micro UAVs flew simultaneously (at respective altitudes of 75, 100, and 125 ft) under the control of a single operator.

The test also marks the first instance scientists have had to evaluate Automated Decision Logic capabilities for multiple in-flight UAVs. Automated Decision Logic enables an operator to instantly revisit a particular threat target given a set of predetermined conditions, such as how much fuel is remaining. These tests were successful, as were similar evaluations of automated search patterns and automated wind compensation. In order to demonstrate further applications of the COUNTER system, the researchers also performed perimeter surveillance missions, as well as missions in which multiple vehicles orbited a single point.

The flight test successfully merged all of the technologies developed under the COUNTER program over the last 3 years. As a result of the test, the COUNTER team was able to collect over 41 gigabytes of video telemetry, still photos, and other critical data. Air Force Special Operations Command provided operational insight into the COUNTER system, while AC-130 Gunship sensor operators controlled and evaluated the multiple UAV sensor video streams. During the test, each operator had the opportunity to employ the tools available for locating targets in urban areas.

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AFRL Participates in Exercise AVENGING EAGLE

AFRL participated in Exercise AVENGING EAGLE, the first US Air Force (USAF) and British Royal Air Force (RAF) coalition training exercise to employ distributed simulation systems to connect operational bases. AVENGING EAGLE linked GR4, F2, and Airborne Warning and Control System (AWACS) simulators at the Air Battlespace Training Centre, RAF Waddington, with (1) an A-10 simulator at Spangdahlem Air Base, Germany; (2) four F-15 simulators at Langley Air Force Base (AFB), Virginia; (3) the AWACS training center at Tinker AFB, Oklahoma; and (4) four F-16 multitask trainers and an A-10 at AFRL's Mesa Research Site, Arizona. The success of AFRL's previously conducted Coalition Mission Training Research exercises—which linked US and United Kingdom (UK) laboratory systems under an International Cooperative Research and Development Agreement—led to a new, 10-year interoperability agreement between the RAF and USAF. This newly forged arrangement prompted the conduct of coalition distributed mission operations (DMO) training via US-based Mission Training Centers (MTC).

Though AFRL first began conducting coalition DMO training research exercises in 2001, with the UK's Defence Science and Technology Laboratory, Exercise AVENGING EAGLE marks the first event linking the UK's Air Battlespace Training Centre to US-based MTCs via the DMO network.

AVENGING EAGLE's four exercise days focused on scenarios over the Joint National Training Center (Fort Irwin, California) database and involved (1) coalition, composite-force air operations in an evolving war with integrated air-to-air and air-to-ground operations; (2) an extended vulnerability period, with hand-over of AWACS from US to UK and defensive counter air (DCA) missions

Exercise AVENGING EAGLE graphic

from UK to US; (3) concurrent operations with offensive counter air and air interdiction missions in the south, rolling to DCA in both the north and the south; and (4) concurrent, multiple operations including close air support, DCA, downed Airman protection, and Combat Search and Rescue mission coordination. Using secure video teleconferencing, warfighters at all sites planned, briefed, executed, replayed, and debriefed coalition-force missions each day.

Overall, participant feedback noted the outstanding training potential of coalition DMO in providing a range of opportunities to work with composite, coalition forces. Further, Air Combat Command will use the many associated technologies, procedures, and training strategies developed and tested at AFRL to leverage distributed simulation exercises as a complement to live-fly training.

Research Leads to Nonlethal Active Denial System

Operational version of AFRL's ADS

AFRL completed an extensive bioeffects research program for an invisible, counter personnel, directed energy weapon known as the Active Denial System (ADS). Researchers performed numerous studies that documented data showing that millimeter waves do not promote cancer or cause reproductive problems. The researchers also defined skin and eye exposure thresholds, as well as levels at which effective repel occurs. These research results demonstrate that the ADS can be used operationally while maintaining a significant safety margin, thus making the device a landmark nonlethal weapon. The bioeffects research effort also assisted hardware developers in their design of the novel weapon. The ADS program marks the first instance wherein a nonlethal weapon was founded on bioeffects research occurring prior to, rather than subsequent to, the weapons development process.

AFRL has been involved in researching the operationally useful effects of millimeter waves for almost 20 years. These wavelengths occur in the 1-10 mm (0.04-0.4 in.) region of the electromagnetic spectrum, which means they are larger than infrared waves but smaller than radio waves or microwaves. Millimeter waves correspond to radio band frequencies of 30-300 GHz. In the late 1980s, AFRL researchers discovered a particular effect of 94 GHz energy that ultimately became the basis for the ADS.

The ADS focuses a beam of millimeter waves occurring at this 94 GHz frequency. The effect is a rapid heating of the human target's (adversary's) skin that is extremely uncomfortable and ultimately prompts the individual to flee the beam. AFRL's Joint Nonlethal Weapons Directorate, the Air Force's Force Protection Battlelab, and the Office of the Secretary of Defense's Advanced Systems and Concepts Office funded ADS development through an Advanced Concept Technology Demonstration (ACTD). The ACTD produced two versions of the system: a mobile version that has since served as a technology demonstrator and a containerized version that is suitable for operational deployment.

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Pulsed-Thermography Inspection Capability Demonstrated for GLOBUS II

AFRL performed an on-site pulsed-thermography inspection of the GLOBUS II radar cover, successfully demonstrating the utility of this new inspection technique and training site technicians in the process. As a result of AFRL's engineering expertise in nondestructive inspection (NDI) and thorough analysis conducted throughout the GLOBUS II program effort, the ongoing safe operation of the GLOBUS II radar system remains assured.

The US-developed GLOBUS II radar system serves as part of the 29-sensor, global space surveillance network that provides critical data to US Strategic Command. Located in Vardo, Norway, and operated solely by Norwegian personnel, GLOBUS II radar has proven effective at identifying more than 10,000 man-made objects orbiting the earth. The radar is sheltered by a composite fabric cover manufactured by Saint-Gobain Performance Plastics. Fabricated in sections joined via hot bonding, the cover is secured to the structure that houses GLOBUS II but otherwise hangs above the radar so that no direct contact occurs. Pressurized air (with effects similar to those that loft a balloon) keeps the cover suspended over the radar.

AFRL's Structural Materials Evaluation Team supported the recent demonstration by devising and conducting a program to test a robust NDI procedure for evaluating the joined areas (hot-bonded sections) of the radar cover. The procedure employs ThermoScope®II, a pulsed-thermography inspection system manufactured by Thermal Wave Imaging, Inc. ThermoScope II consists of an inspection hood that contains an infrared (IR) camera and high-intensity flash lamps connected directly to a ruggedized laptop computer. During an inspection, the technician places the inspection hood directly on the surface area of interest and applies heat using the flash lamps. The system processes real-time (up to 300 frames per second) IR thermal data for the selected surface, with postprocessing and all applicable results displayed on the laptop. The collected data can effectively identify even subsurface areas that are not bonded; these potential problem areas are then subject to disposition by the responsible engineering authority for repair and/or recurring inspection. This pulsed, or flash-based, method represents the state of the art in thermography-based inspection techniques.

GLOBUS II

AFRL structural materials evaluation engineer Mr. Kenneth LaCivita performs a pulsed-thermography inspection in Vardo, Norway.

During the demonstration conducted on-site in Vardo, the newly trained Norwegian technicians (all of whom were also certified rope climbers) first assisted in many of the inspections and then went atop the radar cover (a height exceeding 100 ft) to inspect additional areas of interest. While inspection results indicated the presence of unbonded areas in the new cover, radar prime contractor ITT Industries subsequently determined that the size and location of the identified defects posed no threat to the cover's integrity. These specific defects, however, will continue to undergo periodic monitoring. Meanwhile, the entire cover is slated for annual inspection.

Robotic Perimeter Security System Proves Viable for Base Defense

The Defender, a robotic platform that performs reconnaissance, surveillance, targeting, and threat neutralization tasks in support of base defense operations

AFRL researchers participated in the Robotic Physical Security Experiment, conducted at Kirtland Air Force Base (AFB), New Mexico. For their role in the effort, the researchers demonstrated the capabilities of the Defender, a robotic platform that performs reconnaissance, surveillance, targeting, and threat neutralization tasks in support of base defense operations. This state-of-the-art robotic technology enables security forces to patrol perimeters and check breaches without stepping into harm's way, increasing the safety of military personnel and the protection of assets.

AFRL researchers visited Kirtland AFB to perform the experiment with the 377th Security Forces Squadron (377 SFS). In preparation for the activity, they first placed vehicle and personnel detection sensors in the ground around the selected perimeter and then arranged the radar. After setting up the Operation Control Unit in a mobile command post, the researchers trained 377 SFS Airmen on the robot's operation. Once adept at these operational techniques, the Airmen commenced exercises involving an "aggressor's" tripping of system sensors. Instead of responding manually to check the alarm, the security forces personnel operated the Defender remotely, sending it out to check and identify the potential adversary. Upon receiving the visual feed supplied by the Defender's camera system, the participants used the radio system to address the would-be aggressor, directing the individual to stop and identify himself. For real-life situations of this nature, the Defender technology also provides Airmen a means for applying deadly force, if necessary, without actually endangering themselves.

The experiment consisted of three different scenarios, effectively testing all of the Defender's capabilities. In the first scenario, exercise participants used the Defender to perform persistent autonomous patrols of the perimeter, without incident. In the second scenario, they used the Defender to respond to a sensor alert of a possible aggressor, who turned out to be a nonhostile local citizen. The third scenario, which began with the Airmen's use of the Defender to perform a routine perimeter check, progressed through a series of events involving the detection, intercept, and neutralization of a hostile aggressor.

Lasting a total of 20 days, the Robotic Physical Security Experiment afforded the AFRL researchers ample time for easily and quickly training the security forces personnel in all aspects of the Defender's capabilities. The experiment also helped the researchers identify areas of the system needing improvement before future use.

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ARTS Technology Clears Massachusetts Military Reserve

AFRL researchers used the All-Purpose Remote Transport System, known as ARTS, to perform range clearance functions at the Massachusetts Military Reserve (MMR). ARTS is a robotic operating platform that uses various attachments to perform clearing tasks in areas deemed hazardous due to the presence of unexploded ordnance (UXO). Demonstrating the effectiveness of the ARTS brush cutter attachment, AFRL personnel used the technology to clear 8 acres of brush and trees from one of MMR's grenade ranges in just 11 days.

For 90 years, MMR (located in Cape Cod, Massachusetts) has served as a military training ground for the armed forces. Decades of constant use have left behind waste ammunition, some of which is still live. The dangerous accumulation of potentially live ammunition not only poses a threat to humans but exacts a toll on the surrounding environment, a confluence of factors highlighting the urgent need to clear the ordnance. To minimize downtime and maximize cleanup, representatives from MMR called upon AFRL to identify a method for clearing vegetation from the grenade range that would ensure safer and more thorough ordnance removal. The lab recommended ARTS for the chore, a decision which—compared to manual cleanup options—cut costs by 30% and required 75% less time to complete.

ARTS is a remotely operated vehicle consisting of a Posi-Track tractor manufactured and distributed by All-Season Vehicle, Inc. The tractor's lightweight construction and low center of gravity make it compatible with several different attachments that can be used for multiple tasks, heightening the vehicle's suitability for range clearance tasks. An onboard robotic command and control package enables remote operation of all tractor functions, including engine start-up and stop, vehicle propulsion and lights, and all attachment operations. The onboard control system is equipped to accommodate up to four cameras, two of which can have pan/tilt mounts. A pair of digital radios transmits command signals from the operator control station (OCS) to the platform, and an independent transmitter/receiver pair communicates audio and video from the platform to the OCS. ARTS is remotely operable across line-of-sight distances up to 3 mi. A camera attached to a retractable pole that can be raised up to 50 ft enables the operator to see above the tree line. The OCS consists of a laptop computer and monitor; the network communication gear, radio frequency transceivers, and antenna network; and a joystick controller box. The computer is a standard personal computer with sufficient processing power, memory, and features for performing the operator functions.

ARTS shown with brush cutter attachment prior to beginning vegetation clearance at the MMR

MMR after completion of range clearance operation

Impressed with ARTS' performance, MMR officials have elected to use the technology again. They have requested that AFRL perform a 3-month geophysical survey of the entire range in order to determine the amount of UXO present throughout the landscape. This activity will enable further demonstration and test of the vehicle's vegetation clearance and ammunition removal capabilities.

Miniature Navigator Demonstrator Evaluated During Field Tests

Next-generation GPS/INS antijam technology mounted atop an AFRL mobile test vehicle to demonstrate weapons navigation capabilities

Next-generation GPS/INS antijam technology mounted atop an AFRL mobile test vehicle

AFRL munitions researchers completed initial field testing of next-generation Global Positioning System (GPS)/inertial navigation system (INS) antijam technology at the Static Antenna Test Range (Holloman Air Force Base, New Mexico). This navigation satellite timing and ranging technology has proven to be a highly effective navigation aid for munitions applications operating in all weather conditions, both day and night. AFRL's Miniature Navigator Demonstrator (MIND) program is the latest to advance the state of the art in this technology area. MIND comprises a reduced-size, reduced-cost GPS/INS integrated weapons navigator that employs high antijam radio frequency front-end hardware, adaptive processing algorithms, and inertial measurement unit technologies.

The field test provided an opportunity to collect baseline performance data on the MIND system's acquisition and tracking performance. Engineers used the mobile test vehicle (MTV), an AFRL asset developed to support testing of advanced guidance technologies, to conduct multiple tests in varying conditions. The MTV's avionics subsystems, system control features, and data acquisition hardware and software enable real-time monitoring of the system under test, as well as postprocessing analysis of results.

During the ground tests, researchers exposed the MIND system to extreme GPS jamming conditions. The test results indicate the MIND system's capacity to meet or exceed program performance goals. With the maturity of—and growing reliance on—GPS-aided weapons comes the steadily increasing need to address GPS vulnerabilities. Accordingly, AFRL researchers are very active in the development of GPS-based munitions, particularly those involving GPS antijam technologies.

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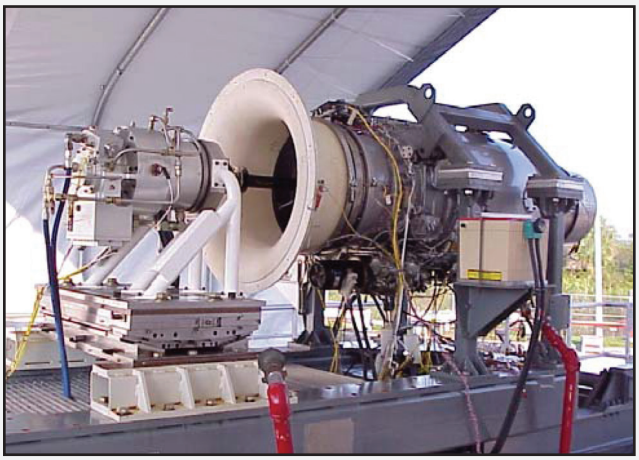
Near-Instantaneous Low-Spool Power Extraction Demonstrated

Engineers from AFRL and industry partner Pratt & Whitney demonstrated a near-instantaneous low-spool power extraction capability as part of the Versatile Affordable Advanced Turbine Engine program. This successful effort marks the first in a series of planned demonstrations geared towards advancing state-of-the-art propulsion technology. Specifically, the demonstrations are designed to elevate the technology readiness level of an advanced power management system capable of delivering the relatively high levels of transient power extraction that future aircraft will demand.

This initial demonstration, which employed a Pratt & Whitney JT15D engine, afforded AFRL engineers the opportunity to explore engine operability as large (270 kW, or approximately 360 hp), nearly instantaneous electrical power loads were pulled directly from the engine's low-pressure spool without the use of a gearbox. As observed, use of the excess power available in the engine's low-pressure spool offers an efficient and integrated solution—one that characterizes a key capacity to rapidly model—and subsequently realize—significant levels of power extraction from a propulsion engine. This advanced capability will benefit a number of future vehicles, including high-altitude intelligence, surveillance, and reconnaissance platforms; directed energy weapons; advanced fighters; and long-range strike aircraft.



Demonstration of near-instantaneous low-spool power extraction using a Pratt & Whitney JT15D engine

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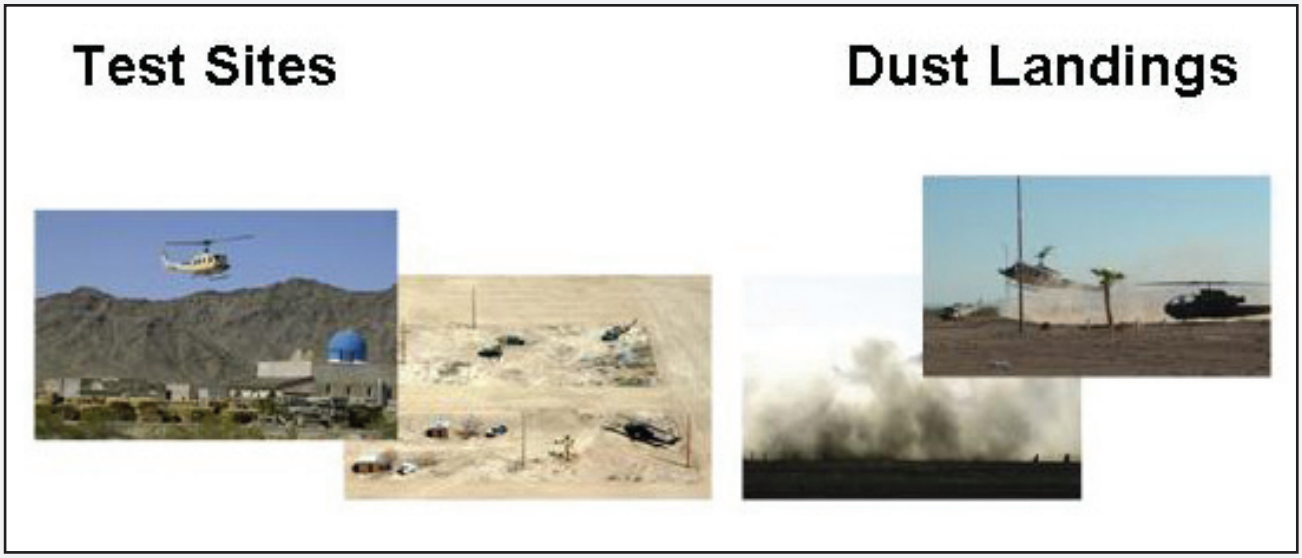
3D-LZ Risk Reduction Technology Undergoes Test



Tests of 3D-LZ high-performance LADAR technology for helicopter brownout mitigation

AFRL tested an industry-developed receiver preprocessor built for an upcoming three-dimensional landing zone (3D-LZ) program aimed at mitigating helicopter brownout via high-performance LADAR [light amplification for detection and ranging]-based technology. The Office of the Secretary of Defense Rapid Reaction Technology Office funded H. N. Engineering Corporation's development of the risk reduction device, and the Defense Advanced Research Projects Agency Strategic Technology Office funded its testing, which AFRL conducted using a dust course and properly equipped helicopters at the Army's Yuma Proving Ground (Arizona). The preprocessor discriminates dust returns from hard-target returns, a critical distinction for pilots working to overcome the potentially catastrophic effects of backscatter during rotorcraft approach and landing in dry, arid environments or similarly dusty (i.e., brownout) conditions.

H. N. Engineering developed the preprocessor based on previously applied techniques—specifically, those that the company used in devising the height-above-ground, all-weather laser fuze component of the Army's Land Attack Standard Missile. The preprocessor underwent subsequent incorporation into a SEEBAIR LADAR system that also included a two-axis scanning capability.

Researchers used the risk reduction preprocessor to collect thousands of ground-based data records as helicopter flybys generated dust clouds. Likewise, the unit's integration into the SEEBAIR system installed aboard a UH-1 helicopter ensured the capture of ample airborne data as well. The research team conducted evaluations during fully obscured landings, both at the Yuma obstacle course and at theater-realistic test sites. The ground and airborne data will facilitate preprocessor performance validation; it will also contribute to further development of the technology. The results of this test indicate that the receiver preprocessor will provide significant risk reduction for AFRL's 3D-LZ high-performance LADAR program.

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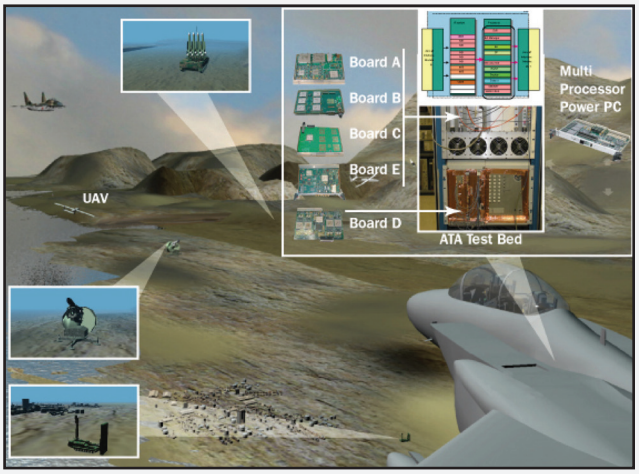
Advanced Threat Alert System Developed and Demonstrated

AFRL engineers developed and demonstrated an advanced digital-receiver-based threat alert system that provides airspace buyback through air defense system warning, situational awareness, targeting, and countermeasures. Users of the new system will benefit from its passive and real-time detection, identification, and location of advanced radars, as well as its flexible, modular architecture, which will permit the system to evolve in response to changing requirements.

The advanced threat alert system (ATAS) possesses the unique capability to perform all warning, targeting, and countermeasure functions concurrently. The system's digital receivers are based on the latest commercial hardware and advanced signal-processing algorithms. Further, the modular approach used to create the ATAS simplifies platform integration and facilitates the technology's insertion into combat and support aircraft and unmanned air vehicles alike.



Graphical depiction of AFRL-developed ATAS

"First Light" Achieved on Intensity Correlation Imaging Telescope

An intensity correlation imaging ("light bucket") telescope

Professor David Hyland, an AFRL-funded research scientist at Texas A&M University, achieved "first light" on a ground-based, proof-of-concept telescope system. Designed to enable imaging of objects in geosynchronous earth orbit (GEO) via a single, multiple-aperture, low earth orbit satellite, the concept employs multiple "light bucket" telescopes. Also known as intensity correlation imaging telescopes, these devices measure the intensity of incoming light, immediately converting these signals to time-tagged digital data for correlation and processing. Subsequent creation of actual imagery requires complex postprocessing of captured data. This technology establishes the viability of creating very large apertures without complex tooling or nanometer-scale metrology systems.

The AFRL-sponsored experiment will initially involve imaging a star with the concept system. During additional experiments, conducted after this preliminary effort, the telescope system will perform planetary and GEO object imaging. Ongoing program activities will leverage an award received from the National Reconnaissance Office Director's Innovation Initiative to pursue further development of the single-satellite, multiple-telescope concept, as well as to verify associated signal-to-noise performance.

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New Water Purification Device Undergoes Field Testing

AFRL worked with Seldon Technologies to develop filtration technology that transforms groundwater into potable water without electricity, ultraviolet light, harsh chemicals, or prolonged heating. The lab distributed this purification capability—in the form of two different devices—to Fort McCoy, Wisconsin, for field testing. Both devices employ enmeshed carbon nanotube filters to remove bacteria, viruses, endotoxins, and other molecular contaminants (e.g., heavy metals, halides). The WaterBox™ can clean up to 1,200 gal at 1 gal/min, making it suitable for supplying entire units. Meanwhile, the smaller, lighter-weight WaterStick™ is ideal for personal use, offering a 70 gal cleaning capacity and incorporating easily into individual hydration backpacks. In addition to being field-tested for ruggedness and operability on Fort McCoy ranges, both variations underwent evaluation during the National Guard Patriot 2008 exercise.

WaterStick (pictured top left) and WaterBox (pictured top right)
Member of the 194th Air Support Operations Group, Air National Guard (pictured bottom left);
labeled water samples

Experimental Equipment Enhances TACP Capabilities

Mr. Gregory Burnett (pictured left), chief engineer at AFRL, explains to Senior Airman Nicholas Halladay (pictured right) the MR-1 computer's capacity to send Global Positioning System satellite coordinates to an aircraft (photo courtesy of US Air Force Airman First Class Jonathan Snyder).

Tactical Air Control Party (TACP) Airmen tested lab-developed equipment concepts during Northern Edge 2008, a joint training exercise hosted by Alaskan Command. TACP Airmen, whose job it is to navigate miles of often rugged terrain in order to call in air strikes enhancing combat operations, routinely carry close to 100 lbs of equipment. AFRL's experimental equipment decreases this cumbersome load by 10-15 lbs. Designed to facilitate lighter, faster, more effective TACP missions, the AFRL-engineered technology utilizes a renewable integrated tactical energy system—a lightweight, self-contained, battery-powered generator—capable of producing enough energy to power all of the TACP equipment. Airmen use the system's head-mounted display to identify potential downrange threats and a small, ruggedized MR-1 notebook computer to view, store, and send information directly to pilots.

Conducted at locations across the Pacific Alaska Range Complex, Northern Edge is one of a series of US Pacific Command exercises that prepare joint forces to respond to crises in the Asia Pacific region. The 30 TACP Airmen who participated in the 2008 exercise field-tested AFRL's experimental equipment for potential use in future operations, evaluating its utility in various land navigation and close air support training operations conducted during the event. The feedback received from the TACP participants throughout several rounds of testing will assist the lab's efforts to improve the equipment prior to its use in actual combat situations.

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Reentry Structures Experiment Completes Brief Hypersonic Flight

Launched from White Sands Missile Range (New Mexico) aboard a Navy-supplied sounding rocket, the AFRL-developed Reentry Structures Experiment (RESE) successfully completed a 6 min hypersonic flight, traveling at Mach 5 to an altitude of 95,000 ft before landing 21 mi from the launch point. RESE comprised six innovative payloads; these onboard experiments included a new acoustic protection system, a new reconfigurable hardware architecture for responsive space satellites, two novel thermal sensors, a new high-temperature material, and a flexible circuitry tryout. The overall objective of AFRL's RESE program was to develop a low-cost approach for flight-testing numerous experiments, including associated hardware, for future satellites and space exploration missions.

RESE incorporated six innovative experiments into a single vehicle to achieve maximum payoff. The acoustic test measured the performance of a hybrid acoustically layered foil (HALF) foam. Applied to the inner lining of the rocket fairing, this treatment is designed to reduce noise that might damage sensitive launch vehicle instruments. At low frequencies, the HALF foam demonstrated performance results three times improved over traditional treatment systems. The Responsive Space Bus Demonstration validated the feasible use of a reconfigurable hardware architecture for quickly assembling satellites in response to changing mission needs. This new architecture bears similarity to the well-established plug-and-play concept in use for desktop computers.

RESE's two onboard thermal sensors consisted of an ablation sensor and a heat flux gauge. Provided by the National Aeronautics and Space Administration (NASA), these devices measure the performance of thermal protection systems for reentry vehicles. NASA will also employ these sensors on the Crew Exploration Vehicle, the proposed successor to the space shuttle. Commercially developed by Ocellus, Inc., the high-temperature material incorporated into RESE underwent evaluation as a potential insulation material for protecting reentry vehicles. Supplied for the effort by Q-Flex, Inc., the thin, flexible circuitry launched aboard RESE promises to reduce the mass of aerospace cabling by 50% to 70% and is therefore a candidate for inclusion in future satellites, missiles, and aircraft.

A Navy sounding rocket launches from White Sands Missile Range, New Mexico, with AFRL's RESE aboard.

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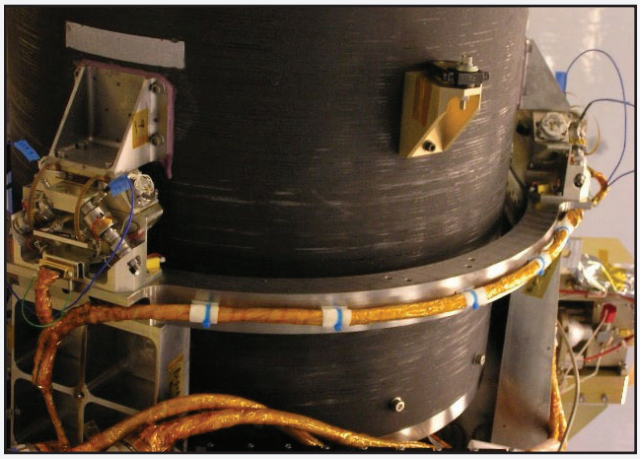
Twofold Improvement of System's Vibration Isolation Capacity



AFRL's MVIS-II

AFRL's TacSat-2 experimental tactical satellite successfully completed the unlock sequence for the Miniature Vibration Isolation System-II (MVIS-II), prompting immediate improvement of on-orbit passive vibration isolation between satellite bus and payload. Specifically, MVIS-II now demonstrates twice its original capacity for passive vibration isolation. Engineers from AFRL and Honeywell Defense and Space were involved in performing the additional tests associated with this MVIS-II enhancement.

Leveraging a design entailing its active control of "smart" materials, MVIS-II is able to isolate sensitive optical payloads from vibration over a wide range of bandwidths. Further, this miniature hybrid (passive/active) isolation system accommodates changes to payload mass properties and geometry, requiring only minor modifications to support structures and thereby offering yet another significant improvement over previous system designs.

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Technology Transfer

Page

Fiber Laser Research Benefits From Lab Funding

AFRL-funded researchers created fiber lasers as thin as a human hair. Dr. Jerome V. Moloney, director of the Arizona Center for Mathematical Sciences, located in Tucson, heads up the research team. During the course of the AFRL-sponsored program, his team developed unique technologies enabling the integration of laser-active ions into fully functional and packaged fiber laser devices.

The availability of ultrafast fiber lasers will provide compact and cost-effective solutions spanning a number of technologies with direct relevance to the Air Force. The new technology enables the replacement of cumbersome and expensive ultrafast laser sources with compact, hardy, and economical fiber-based devices that will link laser research with real-life applications.

The research established four world records for continuous-wave, single-wavelength fiber devices. By using special glass fibers with high ion concentrations, the researchers were able to generate record-breaking peak power with the compact, economical, all-fiber devices. The team envisions further development efforts involving fully functional prototypes of fiber laser sources that can be transported and tested in the field.

Dr. Moloney's team is licensing the technology for commercialization through the University of Arizona's Office of Technology Transfer and is also working with AFRL to transition the technology. The team is now looking into new military applications that will create opportunities in the areas of materials processing, nonlinear optics, and terahertz remote sensing.

Fiber laser

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AFRL and GNC to Study Effects of Whey Protein on Warfighter Performance

AF test subject assesses the impact of specialized whey protein.

Researchers from AFRL and General Nutrition Centers (GNC), Inc., kicked off a unified effort to determine whether a specialized form of whey protein—a pure, natural, high-quality protein derived from cow's milk—can aid warfighter strength and alertness during fatigue-inducing missions. This joint venture, enabled through a Cooperative Research and Development Agreement, represents the first clinical collaboration between the Air Force (AF) and GNC.

The team will examine the specialized whey protein's effects on the mental and physical performance of individuals subjected to long hours without sleep. The nature of work performed by warfighters such as aircraft pilots and crew, and particularly Special Operations Forces personnel, often demands that these individuals remain awake for periods of more than 24 hours. Further, many civilian occupations—airline pilot, firefighter, and trucker, for example—have similarly rigorous requirements.

GNC will supply the specialized whey protein and placebos needed for the effort, while the AF will provide up to 50 military test subjects, along with the facilities and equipment needed for assessing and analyzing results. This research may ultimately furnish the AF with a nonpharmaceutical option for bolstering warfighter strength and endurance during lengthy, high-performance missions. A readily available alternative would not only reduce the reliance on pharmaceutical products, some of which cause undesirable side effects, but would also lessen the potential liability associated with the use of such products. In turn, GNC would benefit from the establishment of an enhanced commercial product line benefiting the many members of the civilian population whose own work entails intense concentration and physical stamina.

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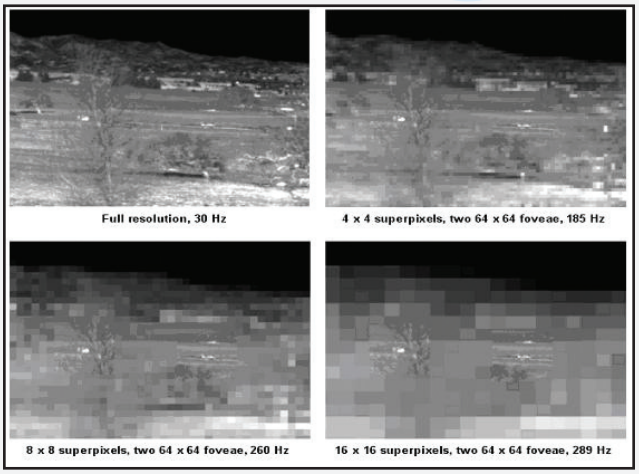
Lab Demonstrates Biologically Inspired Foveal Sensing in Infrared Cameras

Under an AFRL Small Business Innovation Research contract, Nova Sensors developed a family of camera systems providing variable-acuity superpixel imaging (VASI™) capabilities. This advanced imaging technology permits maximum-resolution focus on regions of interest from the visible to infrared spectrum, while significantly reducing the bandwidth required for image readout and processing. The VASI-based cameras' built-in capacity for frame-to-frame, dynamically programmable spatial resolution emulates the biological paradigm of foveal vision.

The biological makeup of the human eye entails a small area of high resolution (the foveal region), with radially decreasing peripheral clarity. VASI technology mimics the human foveal vision system's function, in that (after performing on-chip spatial binning) system sensors sample the "most important" image information at high spatial resolution and the "less interesting" information at lower spatial resolution. This guarantees that key image content is preserved. It also ensures both that the total field of view (FOV) is always monitored (should other interesting objects appear in the periphery) and that the highest possible frame rates are produced for a fixed bandwidth or, alternately, for the lowest possible bandwidth. Thus, even as VASI sensors are capturing and retaining essential image content, they are reducing the amount of image data received from large-format focal plane arrays (FPA).

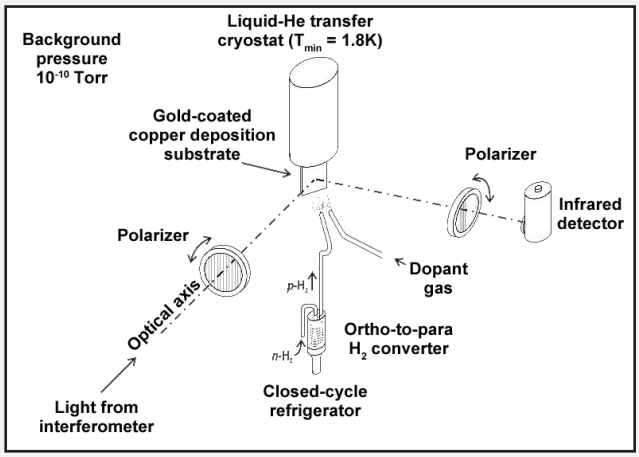
An integrated-circuit architecture enables VASI readout of the entire FOV at high frame rates. The integrated circuitry facilitates this coverage by permitting larger pixels—superpixels—to be dynamically formed on the FPA in regions of relative unimportance, thus reducing the total number of pixel values that must be multiplexed off the FPA. In addition, this architecture can accommodate multiple high-resolution foveal regions "flown" around the imager's FOV at a frame rate that facilitates sampling of critical targets at the highest possible spatial resolution the imager can produce.



In this example of multitarget tracking, an image sequence reveals the frame rate with varying levels of spatial superpixelation; as superpixel size expands, frame rate increases for a fixed number of high-resolution "foveal" pixels.

The applications for multiresolution sensor (i.e., "foveal") architecture are plentiful. One such use of this biologically inspired technology lies in multiple-target tracking, wherein target characteristics such as vehicle motion demand incorporation of representative foveae in order to generate sequential imagery that reflects not only high-frame-rate operation but also the required level of information recovery for mobile objects of interest.

Polarization Spectroscopy Technique Probes Cryogenic Moderators for Radiation Damage



Schematic diagram of the apparatus used to produce and characterize solid parahydrogen

Determining the properties of exotic materials can be challenging, especially when samples are cooled to temperatures near absolute zero and exposed to harsh, ionizing radiation. Accordingly, AFRL scientists developed a technique to overcome the significant obstacles unique to such cryogenic materials research. The technique, which uses polarized infrared light, is currently providing new insights regarding the physical and chemical properties of solid parahydrogen as a quantum solid, which exists for these experiments at temperatures near 2 K. The capacity to monitor the properties of this cryogenic solid throughout its exposure to beta and gamma radiation is critical to Air Force efforts geared towards improving the efficiency of positron moderators. These moderators are a key component of positron-based defect-characterization apparatus and represent an incremental step towards future antimatter energy storage devices.

Solid parahydrogen is known to exhibit long-range order, powerful self-annealing behavior, and very low defect concentrations, making it a promising candidate for positron moderation. By studying the infrared absorption spectra of impurities intentionally doped into the solid, researchers can obtain information about the solid's temperature variations, homogeneity, and crystal packing structure. The AFRL-developed polarization spectroscopy technique not only examines the dependence of these absorption spectra on the orientation of linearly polarized infrared light, but is a particularly helpful mechanism for grasping poorly understood phenomena such as energy dissipation processes, the distribution of charges produced in a moderator during irradiation, and the alignment of polar clusters that self-assemble in doped moderators.

Moderators reduce the energy of β^+ particles from relativistic to thermal velocities, at which they are easily manipulated—via electric and magnetic fields—for a variety of applications. Today's state-of-the-art moderators have efficiencies of less than .5%, a deficiency widely attributed to defects in the moderator and damage to the sample sustained during irradiation. Controlling and monitoring the crystal and its imperfections should lead to more efficient moderators, and polarization spectroscopy is proving its critical role in this endeavor. AFRL introduced its newly established polarization technique at an international conference on matrix isolation and is currently working to transfer the technology to several academic laboratories around the world.

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Miniature Reconfigurable Sensor Processor Developed for UAV Applications

AFRL developed a reconfigurable sensor processor suitable for unmanned air vehicle (UAV) applications. The unit's compact dimensions reflect the engineering effort to reduce not only the size of existing high-performance computing devices, but the associated power requirements and weight as well. AFRL's portable new real-time processor is powerful, too; based on a synthetic aperture radar (SAR) back-projection benchmark, it demonstrated a 36 times improvement in processing time over a 2.8 GHz Intel® Xeon® microprocessor.

SRC Computers, Inc., devised the miniature unit's unique architecture, which pairs a general-purpose processor with the company's own MAPstation™—a reconfigurable processor based on field-programmable gate array technology. Once employed exclusively for traditional high-performance computing applications, the original MAPstation architecture has now undergone adaptation and ruggedization for use in embedded UAV applications, including sensor payloads.

The product improvements and applications realized as a result of this effort have led to several deployments of the SRC Computers system throughout both the Department of Defense and the private sector. Lockheed Martin selected SRC's MAPstation for use as the signal data processor in the Army's Tactical Reconnaissance and Counter-Concealment Enabled Radar (TRACER) program. TRACER will use a system containing four MAPstation processors to perform real-time SAR processing aboard the Warrior UAV.

Portable MAPstation processor created by SRC Computers, Inc.

Meanwhile, the Air Force Precision Image Tracking and Registration (PITrackR) program will use the portable MAPstation unit developed specifically for AFRL. General Electric Aerospace selected the miniature processor for PITrackR's use in detecting and tracking targets from an Arcturus T-16 small UAV. The 4 lb sensor processor will connect to an 11-megapixel camera through a CameraLink interface in order to perform onboard image processing and metadata correlation.

Restraint System Improves Mobile Aircrew Safety

AFRL's UMARS (photo by AFRL's Chris Gulliford)

A new restraint system based on the same technology that brings speeding roller coasters to a smooth stop may soon help save warfighter lives and reduce military mobile aircrew injuries. AFRL engineers teamed with Wolf Technical Services, Inc., under a Small Business Innovation Research contract to develop the Universal Mobile Aircrew Restraint System (UMARS). The collaborative effort was largely a response to Air Force statistics indicating the need for an improved helicopter safety system for loadmasters, flight engineers, medics, pararescuers, and gunners—all of whom must remain mobile while working in the cabin of military aircraft under unpredictable conditions.

Data from Air Force Special Operations Command pointed to slack in existing tether systems as the culprit precipitating five fatalities in incidents defined as "Class A survivable crashes." UMARS is a smart system that automatically self-adjusts tension level based on the severity of flight maneuvers or anticipated impacts. This new restraint system enables a crewmember to adjust his or her tether incrementally, to a total length of 8 ft. This feature accommodates freedom of movement throughout the cabin during normal flight. During a violent maneuver or crash, UMARS increases tension fluidly in order to soften the impact of being restrained.

Current military aircraft restraints consist of either a long, fixed leash or a locking, inertia-based system, each with inherent shortcomings. For example, the fixed-leash system requires constant manual adjustments to ensure safe mobility; if a mishap occurs when the fixed tether is too far extended, the crewmember could actually be ejected from the aircraft. Meanwhile, the inertia-based system locks up if the reel rotates too quickly; its retraction force increases with tether length, meaning that crewmembers may find it difficult to remain standing with a fully extended tether; and once unhooked from a safety harness, its webbing can retract violently into the reel like an oversized, lethal tape measure.

In contrast, UMARS is designed specifically to meet the rigorous demands of military flight and to attenuate energy without unnecessarily stopping motion entirely. It is suitable for use at multiple locations in an aircraft due to its adjustable maximum working length. Further, once UMARS engages, it is easily released with just a small pull.

Other UMARS applications include fixed-wing military aircraft such as the C-130, as well as commercial medical transport aircraft, tall-building escape systems, and fall-arrest systems for construction workers, aircraft maintenance personnel, and others who rely on safety restraints for work accomplished high above the ground.

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Live-Virtual-Constructive Concept Shows Potential for Improving JTAC Training Capabilities

AFRL researchers demonstrated a real-time, real-world live-virtual-constructive (LVC) concept for improving the quality and efficiency of training delivered to joint terminal attack controllers (JTAC)—Air Force (AF) troops who operate within Army units to identify targets and coordinate close air support. The capability may eventually benefit fighter pilots and Air Support Operations Squadron personnel who execute the battle plans developed at Air and Space Operations Centers as well. Researchers demonstrated the training technology by linking two F-16s in flight over Arizona with two high-fidelity F-16 simulators and the new proof-of-concept Joint Terminal Attack Control Training and Rehearsal System, a 5 m diameter immersive simulation environment located at the Orange County Convention Center (Orlando, Florida).

This one-of-a-kind LVC system can close existing training gaps and usher in a new military training philosophy—one that emphasizes the unique training needs of the individual. The new capability will enable military training to be geared towards identifying competencies and strengthening an individual's known weaknesses.

AFRL worked in collaboration with Air Combat Command to create this mission-essential-competencies concept for providing the AF the ability to define and measure warfighter competencies in the live and virtual environments used for operations and training. The AF has adopted this methodology as a means of routinely tracking mission performance and training needs. The LVC concept seeks to apply this competency-based training methodology to live fighter cockpits so that researchers can define, measure, and analyze the competencies of pilots actively engaged in flying an aircraft.

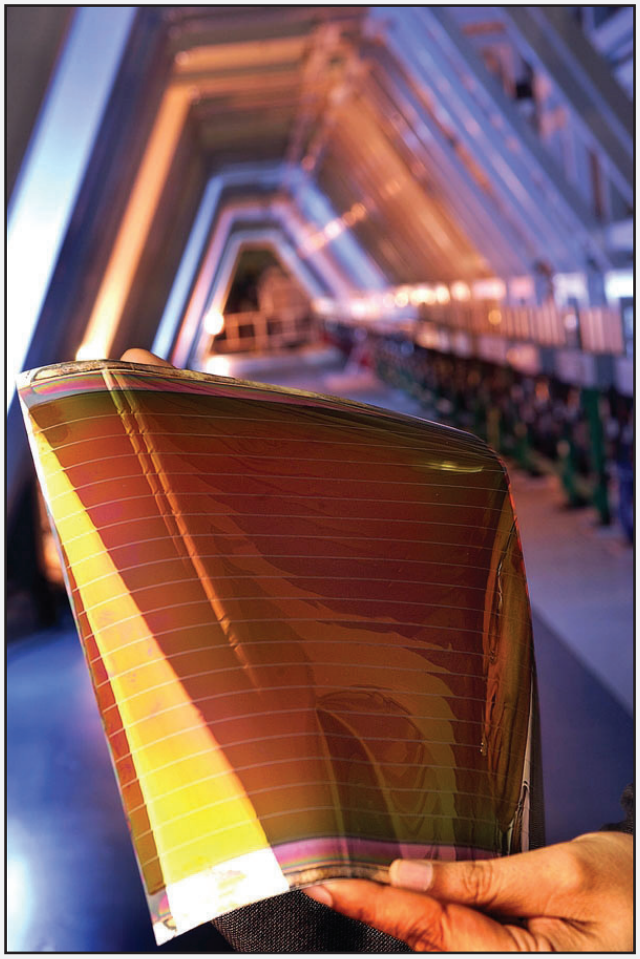
Staff Sergeant Dennis Krouse, of the 9th Air Support Operations Squadron, calls for F-16 close air support on enemy positions inside the virtual environment of AFRL's Joint Terminal Attack Control Training and Rehearsal System (photo by AFRL's Gina Cinardo).

AFRL is partnered with Cubic Defense Applications, a range instrumentation and architecture software systems developer, to provide the interface between aircraft and ground-based systems under a Cooperative Research and Development Agreement (CRADA). The team will combine aircraft data with simulator and classroom data for incorporation into an all-encompassing training database from which each warfighter will construct a training plan tailored to his or her individual strengths and weaknesses.

AFRL plans to collaborate with Boeing under another CRADA to continue development of the aircraft training system. The AFRL/Boeing team will also demonstrate proof-of-concept mission-performance data gathering for the AF, as well as provide higher-quality postaction data and LVC lessons learned.

Advances in SBIR-Developed Solar Cells Prepare Technology for Space Use

Air Force SBIR/STTR



Solar cell

Engineers from AFRL and United Solar Ovonic, LLC, established a new program geared towards expanding technology developed under previous Small Business Innovation Research (SBIR) projects. As part of implementing this venture, AFRL signed an 18-month contractual option outlining the development of new solar cell technology tailored for space and airship vehicle use. The option, which carries a price tag under $2 million, will facilitate efforts to engineer next-generation solar arrays designed specifically for Air Force (AF) missions. These cutting-edge arrays will be lighter, more stowable, and less costly than the products currently in use.

The AF need for high-efficiency, ultralightweight amorphous silicon (a-Si) solar cells prompted AFRL to leverage United Solar Ovonic's existing product in creating one conducive to space use. The product—a terrestrial solar cell optimized for use on earth and deposited on a heavy, 5 mil stainless steel substrate—reflects the company's UNI-SOLAR® technology.

UNI-SOLAR space photovoltaic (PV) products offer an ultralight, low-cost alternative to conventional space PV modules made of crystalline silicon or gallium arsenide. Originally developed for terrestrial applications, UNI-SOLAR features triple-junction modules constructed of a-Si–based thin-film alloys and deposited on a 5 mil flexible stainless steel substrate. Space cells employing polymeric substrates have already demonstrated specific powers exceeding 1000 W/kg, a significant improvement over current capability. Since high specific power, radiation hardness, and superior high-temperature performance are all requirements for space applications, the inherent properties of a-Si make it an attractive material for space and airship vehicle use.

Solar cells deposited on thin stainless steel foil are currently undergoing test in AFRL missions such as TacSat-2, an experimental tactical satellite that launched in December 2006, while solar cells deposited on the new polymer substrates will fly as components of upcoming experimental missions.

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Title III Effort Works to Establish Domestic Supplier for Night Vision Systems

AFRL initiated the second phase of a Defense Production Act Title III effort aimed at establishing a domestic supplier for critical night vision systems. Overall, the Title III mission is to create, maintain, or expand assured, affordable, and commercially viable production capabilities and capacities for items essential to national defense. Optical Systems Technology, Inc. (OSTI), is AFRL's identified industrial candidate for this important venture, which will ultimately establish the company as a domestic lens and system supplier—one capable of cost-effective, end-to-end production of monospectral (fused) and multispectral optical surveillance solutions for the warfighter. Introducing a domestic supplier for these technologies will reduce the present need for US military optics designers to transfer sensitive design information to overseas producers. The availability of a homeland supplier should also reduce product lead times and manufacturing costs.

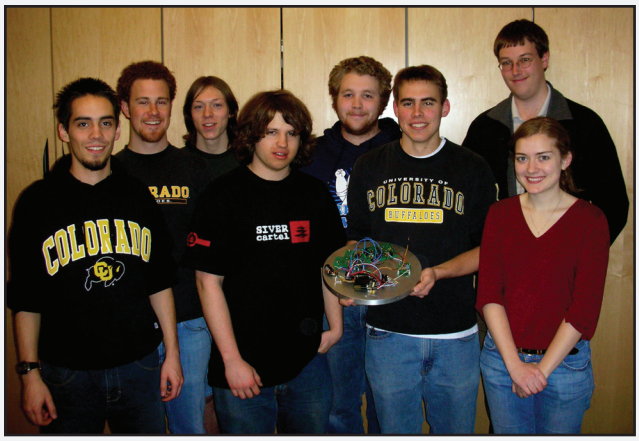
Image surveillance systems—fused and multispectral alike—are prevalent among various agencies of the US Army, Navy, Border Patrol, and Federal Bureau of Investigation, as well as within government entities charged with the oversight of small arms night weapon sights and fire control devices. Further, since portable versions of these multiband systems and their common optical subsystems provide significant weight savings, they are in widespread use by individual warfighter personnel.

The Title III team initiated a technical approach towards developing a domestic supplier. As part of this approach, OSTI was able to expand its production capacity through the acquisition of capital equipment. Accordingly, the team constructed a twofold plan encompassing increased production of shared-aperture systems (which enable transmission of separate wavebands through a common aperture) and automated facilities set up for lens and system production. The plan also emphasized the necessary implementation of lean manufacturing practices and strategic business and marketing approaches.

Small arms featuring night sight technology devised by OSTI

Title III is organized as a Department of Defense–wide activity, with program management occurring at the Office of the Secretary of Defense level and provided by the Director of Defense Research and Engineering. The direct and indirect benefits to defense programs structured around Title III initiatives are substantial, entailing such advantages as increased supply, improved quality, and reduced cost of advanced materials and technologies needed for national defense. Moreover, the Title III influence decreases US dependency on foreign supply sources for critical materials and technologies, proportionately strengthening the economic and technological competitiveness of the US aerospace and defense industrial base.

EPA Signed for Educating and Inspiring Future Aerospace Professionals



University of Colorado students shown with their RocketSat III payload before preflight environmental testing (image courtesy of Chris Koehler, University of Colorado at Boulder student)

An Educational Partnership Agreement (EPA) signed between AFRL and the ACCESS for Education Foundation will give students from kindergarten through high school (K-12) the chance to design, build, launch, and study space-related experiments. This unique opportunity, which also extends to college undergraduate and graduate students, will not only improve student understanding of the scientific environment, but also assist ongoing efforts to attract and develop the next generation of aerospace professionals.

A nonprofit entity under the corporate framework of Microgravity Enterprises, Inc. (MEI), the ACCESS for Education Foundation is devoted to providing educational, public outreach focused on space research, development, and commercialization. One of the foundation's primary functions is to provide free-of-charge rides to space on every one of MEI's commercial sounding rocket launches. As a result, student-developed experimental payloads that would have normally launched from balloon flights will instead be exposed to the actual launch environment. This EPA will help AFRL and its industry partner work towards providing local K-12 schools and area universities with access to space. The hands-on training and experience will aid in attracting and developing future space scientists and engineers. A more long-range goal of the EPA is to facilitate the launch of Air Force experimental payloads under a separate cooperative agreement with MEI.

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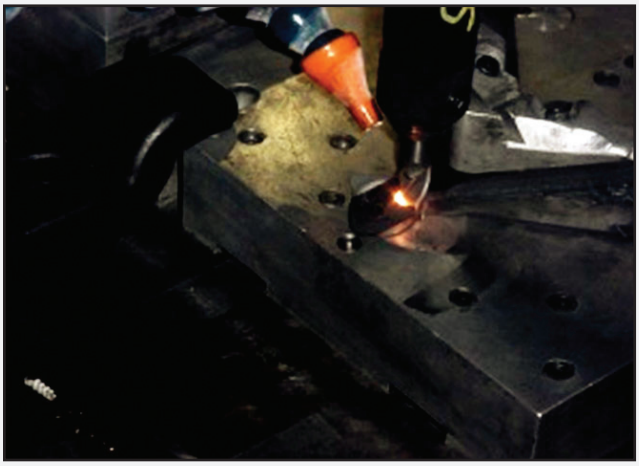
Accelerated Machining Technology Transitions for CMC Engine Component Production

AFRL collaborated with industry for an Advanced Manufacturing Propulsion Initiative (AMPI) to increase material removal rates for profile machining of ceramic matrix composites (CMC). The successful effort, which achieved removal rates increased by more than two orders of magnitude, prompted transition of the accelerated machining technology to Pratt & Whitney, General Electric, and Rolls Royce machining vendors. Lighter than conventional materials and capable of operating effectively in high-temperature environments, CMC components increase gas turbine engine fuel efficiency. Their accelerated machining can save hundreds of hours and tens of thousands of dollars. Applying this technology to a single set of F-35 aircraft engine parts would reduce related machining time by more than 100 hrs and cut associated tooling costs in half. Potential applications include nozzles, blades, vanes, flame holders, and brakes.

The AFRL-industry engineering team—which included participants from TechSolve, General Dynamics Information Technology, General Electric, Rolls Royce, Pratt & Whitney, ATK-COIC, and Goodrich—conducted value stream analysis (VSA) of CMC-based vanes and exhaust nozzles proposed for use in F135 and F136 turbine engines. In every case, the team's VSA activity identified machining as a driver of high cost and lengthy cycle time in the delivery of high-performance CMC components. Accordingly, the AMPI team worked to develop a collaborative approach for addressing issues inherent to machining CMCs.

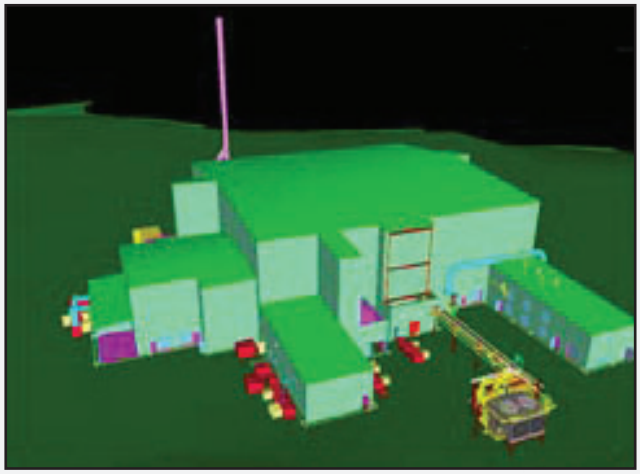
Very hard, brittle, and difficult to cut, ceramic materials are not conducive to machining via traditional methods. Finding cost-effective and efficient ways to machine these materials without damaging them, while crucial, poses a substantial challenge. The situation is further complicated by the nature of CMCs, which are a combination of two ceramic materials and are consequently even more difficult to cut. During this AMPI effort, the researchers validated that improvements made to various aspects of tooling (e.g., materials, geometry, cooling, fixturing) were key to reducing machining cycle time. They likewise demonstrated that such tooling advances reduced associated costs by 80%. The team investigated machining parameters as well, ultimately implementing advanced cutting parameters that increased both depth of cut (from .025 to .100 in.) and feed rate (from 3 to 200 in./min). The researchers used several CMCs in evaluating the effects of their various process improvements and, further, shared important outcomes with major engine contractors involved in F135 and F136 engine production.



Accelerated machining of CMCs

Title III Effort Initiated for Establishing Domestic Beryllium Source

Attendees of the Pebbles Plant ground-breaking ceremony don hard hats and begin digging.



Conceptual drawing of the Pebbles Plant

In partnership with Brush Wellman, Inc., AFRL engineers initiated a Phase II Technology Investment Agreement involving the construction, start-up, and qualification of a beryllium reduction facility meeting Department of Defense (DoD) requirements. A DoD Defense Production Act (DPA) Title III project, the Beryllium Supply Industrial Base initiative will establish the Pebbles Plant, a facility capable of producing 160,000 lbs per year of high-purity beryllium metal. Plant start-up, initial production, and process testing are slated to begin in Fiscal Year (FY) 2010, with demonstration of an initial operational capability anticipated for FY12.

The purpose of this Title III project is to reestablish a domestic source for producing high-purity beryllium metal, a key ingredient in the manufacture of critical system components for weapons, missile defense systems, forward-looking infrared radars for fighter aircraft and attack helicopters, industrial and medical X-ray equipment, and satellite structures. The DPA Title III Program helps to increase the supply, improve the quality, and reduce the cost of advanced materials and technologies needed for national security. Title III reduces US dependency on foreign sources of supply for critical materials and technologies and thereby strengthens the economic and technological competitiveness of the US defense industrial base.

The DPA Title III Program Office, a component of AFRL's Manufacturing Technology Division, serves as the executive agent for the DPA Title III Program. Title III is organized as a DoD-wide program, with program management within the Office of the Secretary of Defense provided by the Director of Defense Research and Engineering (DDR&E). The Title III Program Office identifies and evaluates prospective Title III projects, submits projects for DDR&E approval, structures approved projects, and implements contracting and other business actions relating to projects. The office oversees active projects and provides planning and programming support to DDR&E. The direct and indirect benefits to defense programs resulting from Title III initiatives are substantial.

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Team Receives Award for Excellence in Technology Transfer

A government/industry team composed, in part, of AFRL engineers earned a 2008 Federal Laboratory Consortium Award for Excellence in Technology Transfer. The team received the award based on its contributions to the RoboCrane/Aerial Multiaxis Platform (AMP) program, an effort expected to significantly improve the work environment for programmed depot maintenance personnel by supporting tasks such as aircraft preparation, inspection, coating removal, depaint, and cleaning. Research indicates that the technology's use cuts aircraft depaint time nearly in half and, even more importantly, decreases the possibility of operator stress or injury by at least 70%. In the context of the Air Force (AF) maintenance workload—which includes over 200 aircraft per year, with an average depaint cost of $200,000 per aircraft—widespread use of RoboCrane/AMP could realistically save the AF $8 million annually.

Aircraft coatings removal activities are among the harshest jobs in AF maintenance depots. The revolutionary new RoboCrane/AMP enables depaint personnel to work around large aircraft from the relative safety and comfort of an enclosed cab suspended from the hangar ceiling. As an extension of this technology, a maintenance work platform facilitates the completion of numerous other large-aircraft maintenance tasks outside the immediate depaint arena. This technology leverages years of robotic crane engineering research performed by the National Institute of Standards and Technology. During the lab-sponsored technology transfer effort, AFRL engineers worked with US Technology Corporation under a Cooperative Research and Development Agreement to build and demonstrate RoboCrane/AMP as an operational prototype.

The RoboCrane/AMP capability provides several unique benefits. Its inherent physical stability permits an operator to control the platform from the ground or from a position (while riding) on the platform itself. This flexibility facilitates completion of cargo acquisition tasks, as well as precision placement of large-component assemblies, with no need for additional personnel or other manual assistance. The robotic element accommodates programming inputs that automate the use of trajectories or sensors for maintaining safe standoff distances from the aircraft and otherwise providing collision avoidance. In addition, the technology's distributed, lightweight design enables its installation into existing structures in order to incorporate overhead crane capabilities.

RoboCrane/AMP in use for aircraft coatings removal

Mobile Aircrew Retractor Undergoes Flight Testing

Air Force SBIR/STTR

A C-17 loadmaster tests AFRL's UMARS.

A C-17 loadmaster successfully flight-tested AFRL's Universal Mobile Aircrew Restraint System (UMARS) during the National Guard Patriot 2008 exercise (conducted at Volk Field, Wisconsin). The Small Business Innovation Research–developed system, created in partnership with Wolf Technical Services, consists of webbing that connects to the crewmember's restraint harness or gunner's belt; a retractor reel that keeps the webbing free of slack; and an energy attenuation mechanism that safely slows the restrained crewmember's motion during turbulence, extreme maneuvers, hard landings, and crashes. Initially developed for rotorcraft, UMARS technology now extends to fixed-wing aircraft applications as well.

Prior to the UMARS innovation, military aircraft restraints comprised either a long, fixed leash or a locking, inertia-based system. Whereas the fixed-length belt required ongoing manual adjustment (increasing crewmember vulnerability during unexpected motion or mishap), the inertia-based system's violent retraction force posed a danger all its own. Conversely, the UMARS smart system automatically adjusts tension level according to the severity of the motion or the anticipated impact. It is cousin to the same technology used to ease speeding roller coasters to a smooth stop.

After the flight tests, the loadmaster underwent debriefing and completed a questionnaire, the inputs to which provided researchers with valuable data regarding UMARS advantages and perceived areas for improvement.

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AFRL Partners With Local Health Network for Human Performance Research

AFRL recently embarked on a collaborative research effort with the Kettering [Ohio] Health Network (KHN) to explore the relationship between human stress and fatigue. The primary intent of this joint venture is to identify viable methods for improving human performance in stressful situations. Though commonplace in the warfighter environment, stress-inducing conditions and resultant fatigue are by no means unique to the military. The outcome of this research endeavor thus promises to aid warfighters and civilians alike.

Made possible through a Cooperative Research and Development Agreement between the Air Force and KHN, the program combines the expertise of health industry, academic, and military domains in pursuing innovative solutions and avoiding duplication of effort across these realms. The result is not only a better-protected warfighter but a better quality of life for many members of the civilian community as well. Just as military personnel enduring lengthy missions with little (or no) rest can benefit from novel counterfatigue measures, so too can sleep-deprived professionals in jobs ranging from surgeon to trucker.

One reason for investigating the value of different fatigue-fighting strategies, such as nutritional supplements and alternate training methods, is to minimize the need for chemical intervention and its potential for side effects. Researchers will also focus on advancing medical imaging techniques, as well identifying individualized diagnostic and treatment options for people in poor health. AFRL fatigue countermeasures expert Dr. J. Lynn Caldwell will assist in leading research activity from offices at the Kettering Medical Center (KMC) laboratory. Under separate agreements, Siemens Medical Solutions will place its latest imaging technology at KMC, and the University of Dayton Research Institute will provide researchers.

Colonel Patricia A. Reilly, chief of the AFRL 711th Human Performance Wing, Human Effectiveness Directorate's Biosciences and Protection Division, listens with Ohio Lieutenant Governor Lee Fisher as a panel member explains the Air Force/KHN collaboration to study fatigue and human performance (photo by AFRL's Chris Gulliford).

Tests Completed for CMC Aft Fairing Heat Shield Subcomponent

An aft fairing heat shield on a Boeing 777

As part of a Dual-Use Science and Technology (DUS&T) program conducted with Boeing, AFRL researchers successfully completed the design and preliminary test of an oxide-oxide ceramic matrix composite (CMC)-based structure intended for use as an aft fairing heat shield (AFHS) on military and commercial aircraft. Incorporating the CMC material into the product design would facilitate construction of lighter and less costly AFHS structures.

High-temperature turbine engine exhaust washes over the aluminum struts that hold engines in place on both commercial aircraft (such as the Boeing 777) and military aircraft (such as the C-17). Because this thermal exposure can eventually cause the aluminum struts to fail, engineers use the AFHS structure to protect the struts from the exhaust. The AFHS is most commonly made of titanium, which is an expensive material. AFRL and Boeing entered into the DUS&T effort to study the suitability of a CMC-based AFHS. Boeing also teamed with Teledyne Scientific and ATK-COI Ceramics, Inc. (COIC)—each an organization with considerable experience in the area of advanced CMC design and development.

A COIC-manufactured oxide-oxide CMC became the prime candidate for meeting the AFHS service requirements. The team conducted extensive thermal stress and acoustic load modeling of various AFHS designs that incorporated the identified CMC material. This modeling activity eventually converged on a design that exhibited adequate mechanical properties and also met weight- and cost-related objectives. Using the COIC-produced material and the chosen design, engineers fabricated an AFHS subcomponent and associated T-joints. (A T-joint is a right-angle-shaped joint having no additional layers of composite reinforcement.) The researchers then conducted mechanical testing of the material panels.

The team devoted significant effort both to devising optimal T-joint design and to developing mechanical test methods capable of accurately evaluating those joints. The researchers ultimately found a pi-joint arrangement to be the best configuration. (A pi joint is a right-angle joint having an extra layer of reinforcement on each of its sides. This extra layer is commonly termed a "doubler.") Mechanical testing of the pi joints included tensile loading, which yielded the most revealing results. During tensile load testing, a test machine grips the joint at both ends, pulling until the joint delaminates from the doubler. The test provides information on proof stress, as well as tensile and interlaminar strength.

The team's successful modeling, mechanical testing, and subcomponent fabrication demonstrated the viable use of an oxide-oxide CMC structure as an AFHS. This work may lead to larger-scale testing and, eventually, the manufacture and aircraft testing of a full-scale CMC AFHS.

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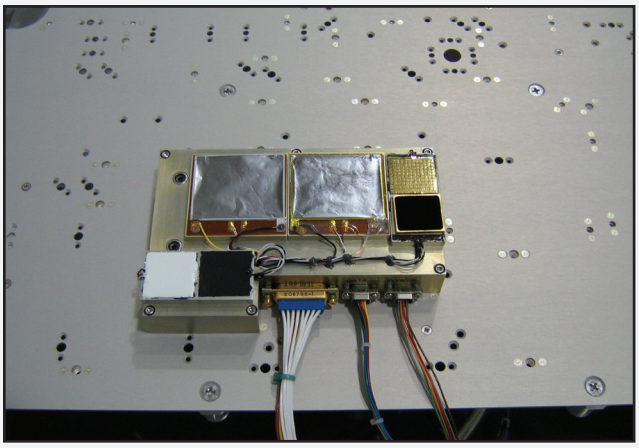
New Device Provides Active Thermal Control of Spacecraft Surfaces

AFRL engineers successfully integrated two existing technologies to create a thermal emission management system suitable for space use. Achieving operationally responsive space capabilities requires versatile satellites that can adapt as needed to accomplish multiple missions. An integral part of such adaptable satellites is a thermal control system enabling real-time, on-orbit temperature control of the spacecraft. In maintaining appropriate spacecraft temperature, the system ensures proper functioning of onboard equipment. AFRL's newly developed thermal emission management system is particularly well-suited for space deployment, since it requires very little power, is compact, and has minimal data storage requirements.

Active thermal management devices generally rely on heaters and mechanical refrigerators to control spacecraft temperature. While these active systems can achieve real-time temperature changes to protect spacecraft from extreme environments, they unfortunately require power supplies and are complex and heavy. Conversely, AFRL's new technology not only requires very little operating power, but weighs considerably less than state-of-the-art active control systems. The integrated device also offers the advantage of on-demand switching between passive and active thermal control.

In creating the efficient new thermal control capability, AFRL engineers paired two technologies developed under separate Small Business Innovation Research contracts. Specifically, the new system combines the functionality of a Sensortek, Inc., electrostatic radiator (ESR) device with a heat-flux-based emissivity measuring method developed by Advanced Thermal and Environmental Concepts, Inc.

After merging the two technologies, AFRL engineers mounted the resultant device inside a large vacuum chamber in order to test it in a simulated space environment. Upon obtaining a steady-state temperature, the test team supplied voltage to one side of the ESR structure, causing the membrane to draw down into contact with the ESR structure's rigid surface. The embedded heat flux sensor demonstrated a very fast response time, so that the engineers were able to monitor the hybrid device's emissivity throughout the temperature change. The results acquired from the ESR structure reflected significant differences in emissivity values—such large differences are a requirement for systems designed to facilitate a wide range of active thermal control.



Two active thermal management surfaces and four passive coatings packaged as part of MISSE-6 (photo courtesy of Sensortek, Inc., and Advanced Thermal and Environmental Concepts, Inc.)

Subsequent to these successful tests, the AFRL-developed device underwent incorporation into the Materials [on the] International Space Station Experiment-6 (MISSE-6) assembly, launched in 2008 aboard the *Space Shuttle Endeavor*. MISSE-6 mission results will aid scientists in determining the new system's viable use for official missions.

New Barrier and Sign Kit for Vehicle Checkpoints

New barrier and sign kit for vehicle checkpoints

AFRL and United Safety Response, Inc. (USR), entered into a Cooperative Research and Development Agreement (CRADA) to advance a novel barrier and sign kit for use at vehicle checkpoints. FirstLink, the US' first National Center of Excellence for first responder technologies, is facilitating the CRADA. The AFRL inventors' goal was to develop a prototype demonstrating a rapid installation capability, while concurrently solving a recognized problem at military checkpoints. Approximately 10% of the vehicles that approach a given military or civilian checkpoint fail to stop, whether purposely or inadvertently. AFRL designed its prototypes to address the challenges of compact storage; rapid, easy deployment; and improved traffic channeling and stoppage.

A partnership between AFRL and the Department of Defense (DoD) Office of Technology Transition makes possible the services of FirstLink, which works to connect DoD organizations with private and commercial entities in advancing first responder capabilities. FirstLink helped establish the contact between AFRL and USR, a company that provides a wide range of barrier technology and perimeter security products. USR researchers plan to combine their internal design and engineering expertise with feedback gathered from AFRL prototype evaluations in order to develop products with the capacity to increase the percentage of vehicles diverted or stopped by nonlethal means. The resulting commercial products will be useful for temporary checkpoints, which typically require rapid installation with minimal resources. Both easy to use and affordable, the equipment constituting the barrier and sign kit will make these units attractive for military, law enforcement, and private facility checkpoint operations alike.

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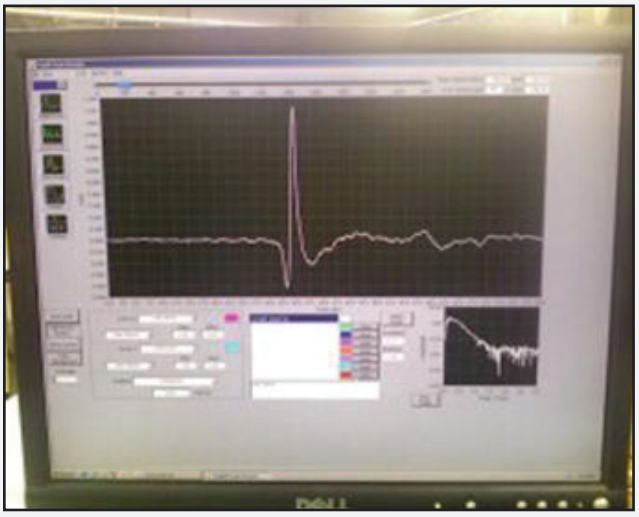
Researchers Conduct Terahertz Research at IDCAST

AFRL and several local Ohio universities—the University of Dayton, Miami University, and Wright State University—are conducting and/or funding research in the emergent area of terahertz (THz) pulse technology. This mutual scientific focus recently yielded the first-ever THz pulse to be generated and detected, an achievement with important implications to a multitude of defense, homeland security, and medical applications. The event occurred during experimentation conducted at the Institute for the Development and Commercialization of Advanced Sensor Technology (IDCAST) Collaborative Research Center, located in Dayton, Ohio. The advanced mode of detection employed for the discovery may ultimately enable the detection of nonmetallic weapons concealed by would-be terrorists. Further, the technology may prove integral to performing various noninvasive medical procedures—early-stage cancer detection, for example.

IDCAST, which received start-up funding from the Ohio Third Frontier Commission, facilitates advanced research of key sensor technologies, from electro-optic and infrared platforms to remote and chemical/biological sensing capabilities. A forward-looking collaborative, IDCAST will drive partnerships between AFRL, academia, and industry towards the joint creation of diverse aerospace, biomedical, environmental, and safety and security technologies.



THz pulse

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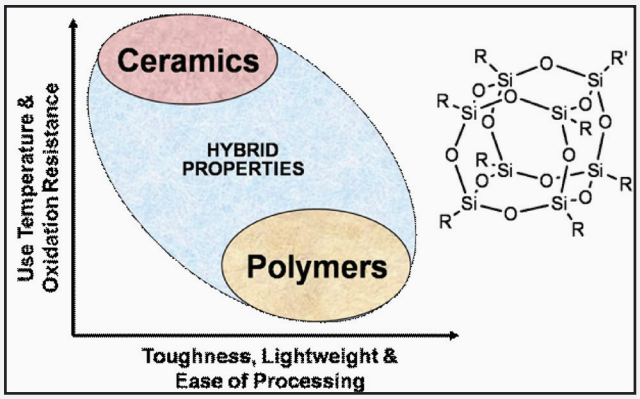
Propulsion Directorate Patents Earn Royalties



Visual depiction of polyhedral oligomeric silsesquioxanes (POSS) hybrid properties

The AFRL Propulsion Directorate's Space and Missile Propulsion Division received royalties for a trio of patents licensed by Hybrid Plastics, Inc. The royalties arose from the company's successful commercialization of a chemical feedstock known as polyhedral oligomeric silsesquioxanes (POSS). Each of the lab's three patents addresses a process for modifying individual POSS molecules in order to instill novel functionality. The subsequent use of these modified chemicals facilitates the production high-performance nanocomposite materials. Development of AFRL's patented POSS technologies occurred at Edwards Air Force Base, California, as a result of in-house, internally funded research.

In recent years, the US Patent and Trademark Office has awarded AFRL a number of patents for POSS-related technologies, several of which have subsequently undergone licensing for commercial manufacture and sale. Discrete and silicate-like, POSS nanoparticles (which are approximately 1,000 times smaller than a single human hair), can be envisioned as the smallest possible piece of sand. Once chemically modified for compatibility and dispersed into common plastics and rubbers, these nanoparticles improve the host material's thermal, mechanical, and wetting properties, thereby creating advanced nanocomposite materials. Among their many uses, these new POSS-based nanocomposites may aid the construction of barrier layers that help to protect surfaces subjected to harsh conditions, such as those common to the rocket propulsion environment.

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Mr. Patrick Rodriguez Earns DoD Technology Transfer Achievement Award

Mr. Patrick A. Rodriguez, principal investigator for the AFRL Phillips Research Site Technology Transfer Support Group, received the 2007 Department of Defense (DoD) George Linsteadt Technology Transfer Achievement Award. The honor recognizes the efforts of individuals whose contributions facilitate the transfer of technology from the DoD to industry. As director of the Technology Transfer Support Group, Mr. Rodriguez works to identify Air Force (AF) technological assets and mechanisms that are potential candidates for transfer to industry, as well as to develop strategies and plans for transitioning those identified technologies.

This award recognizes Mr. Rodriguez for his career achievements towards enabling key legislation, as well as leading the commercialization of Partnership for Optics program results. The proliferation of notable results achieved through his efforts serves as a guidepost for other DoD technology transfer professionals. The honor specifically acknowledges Mr. Rodriguez for his personal facilitation of 235 Cooperative Research and Development Agreements, generating a net contribution to the AF of approximately $149 million; 11 Partnership Intermediary Agreements, worth a total of $1.2 million; and 215 Educational Partnership Agreements, resulting in the transfer of $34 million in used equipment from the laboratory to educational institutions.

Mr. Patrick A. Rodriguez

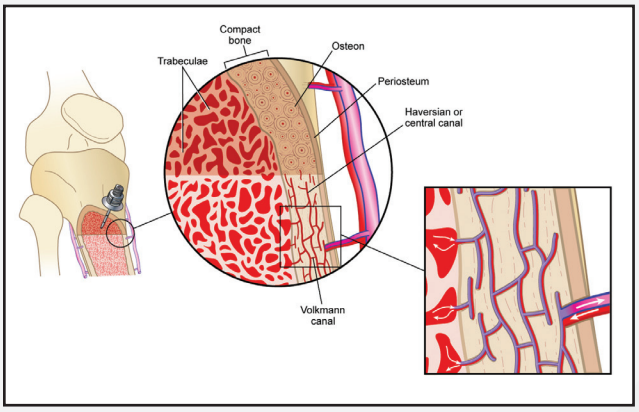
AFRL Gives Combat Medics New Equipment for Saving Lives

Thanks to the outcome of an AFRL/industry Small Business Innovation Research (SBIR) venture, military pararescue jumpers (PJ), combat medics, and field hospital crews now have at their disposal new lifesaving devices—instruments that military doctors expect will greatly improve their chances in saving wounded warfighters' lives. In response to PJ feedback aimed at improving field-deployable devices for intraosseous (IO) access, AFRL initiated a SBIR fast-track agreement. Through the SBIR-based teaming arrangement, AFRL researchers partnered with medical device manufacturer VidaCare Corporation (San Antonio, Texas) to ruggedize EZ-IO®, the company's commercially available bone drill, and to develop a manual IO access system even lighter, smaller, and more efficient than existing technology.

VidaCare's lightweight, battery-powered EZ-IO drill quickly penetrates adult bone to establish an IO port in a person's shoulder, shin, or ankle. This technique enables medical personnel to deliver lifesaving fluids or drugs when a victim's veins cannot support traditional intravenous access. The rationale was not to invent a new drill system but, rather, to leverage the existing one, adapting it to better suit the Air Force first responder mission. That unit, based on the original EZ-IO technology that recently earned acclaim as the nation's top innovation in the *Wall Street Journal* 2008 Technology Innovation Award competition, went into production on November 1, 2008.

Simultaneously, AFRL researchers sought an enhanced tool for PJ use—one that accommodated more insertion sites; weighed less than comparable devices; and was sufficiently rugged to operate in extreme hot, cold, dirty conditions and/or dark places. Thus arose the design of a separate—but related—device that employs manually inserted, disposable needles to achieve IO access. The manual system uses the same drill-tipped hollow needles and catheters as VidaCare's newly ruggedized drill; it is therefore equally effective carried alone or as an EZ-IO backup. Unlike similarly purposed predecessor systems, the new device requires no special extraction tools and, further, is suitable for porting into the sternum in addition to the shoulder, shin, or ankle. The military has purchased about 100 of these devices, and plans are to incorporate the device into the PJ's War Readiness Materials list once the design has been refined to encompass a one-step insertion process.

US Army Chief Warrant Officer 3 Rick Dillinger demonstrates how the EZ-IO® bone drill can access any approved body location, even in the cramped quarters of a UH-60 Blackhawk helicopter. Having established a sternum port on US Navy Master-at-Arms 2nd Class Mark Miller, CWO3 Dillinger is preparing to drill a shoulder port in this proof-of-concept mockup at the Texas Army National Guard's 149th Air Ambulance Unit, Martindale Army Airfield, San Antonio, Texas (photo courtesy of VidaCare Corporation).



Medical professionals consider human bone a noncollapsible vein. This illustration depicts the bone's interior network of connections. It is via this network that fluids or drugs infused into the bone are immediately transported throughout the entire body (graphic courtesy of VidaCare Corporation).

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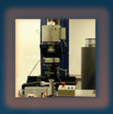


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